U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

AD-A018 806

INVESTIGATIONS INTO THE RELIABILITY OF ELECTROPHOTOGRAPHY

Logical Technical Services Corporation

Prepared for

Defense Supply Service

Defense Advanced Research Projects Agency

30 September 1975

KEEP UP TO DATE

Between the time you ordered this report—which is only one of the hundreds of thousands in the NTIS information collection available to you—and the time you are reading this message, several *new* reports relevant to your interests probably have entered the collection.

Subscribe to the **Weekly Government Abstracts** series that will bring you summaries of new reports *as soon as they are received by NTIS* from the originators of the research. The WGA's are an NTIS weekly newsletter service covering the most recent research findings in 25 areas of industrial, technological, and sociological interest—invaluable information for executives and professionals who must keep up to date.

The executive and professional information service provided by NTIS in the **Weekly Government Abstracts** newsletters will give you thorough and comprehensive coverage of government-conducted or sponsored research activities. And you'll get this important information within two weeks of the time it's released by originating agencies.

WGA newsletters are computer produced and electronically photocomposed to slash the time gap between the release of a report and its availability. You can learn about technical innovations immediately—and use them in the most meaningful and productive ways possible for your organization. Please request NTIS-PR-205/PCW for more information.

The weekly newsletter series will keep you current. But *learn what you have missed in the past* by ordering a computer **NTISearch** of all the research reports in your area of interest, dating as far back as 1964, if you wish. Please request NTIS-PR-186/PCN for more information.

WRITE: Managing Editor
5285 Port Royal Road
Springfield, VA 22161

Keep Up To Date With SRIM

SRIM (Selected Research in Microfiche) provides you with regular, automatic distribution of the complete texts of NTIS research reports *only* in the subject areas you select. SRIM covers almost all Government research reports by subject area and/or the originating Federal or local government agency. You may subscribe by any category or subcategory of our WGA **(Weekly Government Abstracts)** or **Government Reports Announcements and Index** categories, or to the reports issued by a particular agency such as the Department of Defense, Federal Energy Administration, or Environmental Protection Agency. Other options that will give you greater selectivity are available on request.

The cost of SRIM service is only 45¢ domestic (60¢ foreign) for each complete microfiched report. Your SRIM service begins as soon as your order is received and processed and you will receive biweekly shipments thereafter. If you wish, your service will be backdated to furnish you microfiche of reports issued earlier.

Because of contractual arrangements with several Special Technology Groups, not all NTIS reports are distributed in the SRIM program. You will receive a notice in your microfiche shipments identifying the exceptionally priced reports not available through SRIM.

A deposit account with NTIS is required before this service can be initiated. If you have specific questions concerning this service, please call (703) 451-1558, or write NTIS, attention SRIM Product Manager.

This information product distributed by

NTIS U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Final Technical Report

Investigations Into the

Reliability of Electrophotography - Phase III

Sponsored by

Advanced Research Projects Agency

ARPA Order No. 2812

Contract No. MDA 903-75-C028

Principal Investigator:
Dr. John O. Pehek

Contract Period:
July 1 to Sept. 30, 1975

Report Prepared By:
David Faust, Graham L. Gross, Harry J. Kyler*, and John O. Pehek of
Logical Technical Services Corp.
71 West 23rd Street, New York, N. Y. 10010
212-741-8340

*Harry J. Kyler is with St. Joseph's College, Philadelphia, Pennsylvania 19131. He was temporarily associated with LTS Corp. during part of the period of this contract.

ACKNOWLEDGMENTS: Acknowledgments are owed to Dr. William W. Edison of Drexel University and to Drexel University for considerable assistance and advice throughout the period of this contract. We are also greatful to Carl O. Berg and Laszlo Illy, of LTS Corp., who assisted in the preparation of the power supplies and electronic equipment.

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Advanced Research Projects Agency or the U. S. Government.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 1	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Final Technical Report Investigations Into The Reliability Of Electrophotography	5. TYPE OF REPORT & PERIOD COVERED: Final Technical Report 30 June 1975 to 30 Sept. 1975
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): John Pehek, Graham Gross, Harry Kyler, and David Faust	8. CONTRACT OR GRANT NUMBER(s): MDA 903 75 C 0208
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Logical Technical Services 71 West 23rd Street New York, New York 10010	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: ARPA Order 2812
11. CONTROLLING OFFICE NAME AND ADDRESS: Defense Supply Service, Washington Room 1D 245, The Pentagon Washington, D.C. 20310	12. REPORT DATE: 30 Sept. 1975
	13. NUMBER OF PAGES: 83
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Defense Advanced Research Projects Agency Human Resources Division 1400 Wilson Boulevard Arlington, Virginia 22209	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this document is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Distribution of this document is unlimited.

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Corona	Kirlian Photography	Film
Corona Discharge	Photography	Nondestructive Testing
High-Voltage	Electric Field	
Skin	GSR	
Moisture	Electrodes	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Investigations into Corona-Discharge photography show that subjects placed in a High-Voltage field exhibit Corona that may be recorded photographically. The Corona formation and structure depend on the applied field strength and gradient, the type of film used and the waveform and the pulse repitition rate of the applied voltage. Specimen properties affecting Corona formation include resistivity, geometry, and moisture content; other factors may also be important. The discharge mechanism is similar to that of classical point

to plane studies. CD Photography is sucessfully used to study temperature dependence of skin hydration in distilled water and saline solutions. Evidence indicates that variations in certain physiological parameters may be used to determine response to psychological stimuli via Corona Discharge photography.

TABLE OF CONTENTS

ABSTRACT

Investigations into corona-discharge photography show that subjects placed in a high-voltage field exhibit corona that may be recorded photographically. The corona formation and structure depend on the applied field strength and gradient, the type of film used, and the waveform and the pulse repetition rate of the applied voltage. Specimen properties affecting corona formation include resistivity, geometry, and moisture content; other factors may also be important. The discharge mechanism is similar to that of classical point to plane studies. CD Photography is successfully used to study temperature dependence of skin hydration in distilled water and saline solutions. Evidence indicates that variations in certain physiological parameters may be used to determine response to psychological stimuli via corona discharge photography.

SECTION I

INTRODUCTION

This report describes the results of three months work under ARPA Order 2812 amd 2. (MDA 903-75-C028). The project, "Investigations Into The Reliability of Electrophotography - Phase III" is the final phase of our studies into Corona-Discharge Photography. This work began on 25 June, 1974, and has been funded in its entirety by the Advanced Research Projects Agency (ARPA), Department of Defense.

During this period, there were four main areas of work. (1) Experiments and theoretical analysis to tie together the work of the preceding year, (2) Design and construction of an apparatus to allow the study of some frequency-dependent characteristics of corona, (3) A preliminary evaluation of possible applications, and (4) Studies of the corona signatures of human finger tips.

The results of Phase-III are summarized in Section II. Section III is a brief review of corona-discharge photography as developed during our program. Sections IV and V describe the experimental results and apparatus of Phase III, and possible applications are discussed in Section VI.

SECTION II

SUMMARY OF RESULTS

2.0 GENERAL RESULTS

When we began investigations into corona-discharge (CD) photography, little was known in the U.S. about the phenomenon. Russian workers had reported, superficially, the results of several experiments, and had implied an in-depth investigation of theory and applications. In this country, persons, primarily psychologists, had attempted to investigate CD photography (commonly referred to as Kirlian photography), but were mostly unsuccessful in obtaining anything other than irreproducible results and speculative conclusions.*

During the course of our work, LTS has been able to develop a general model for the CD-photography experiment that explains most all of the CD-photographs taken at LTS and elsewhere. We have been able to explain, on the basis of our model, every example of "mysterious or parapsychological" photographs that we have investigated as the result of special and/or uncontrolled experimental conditions. The fact that we mention this early in our discussion here is not intended to reflect the main emphasis of our work, but rather to deal with the considerable and widely publicized misinformation on CD-photography, discussed under the name "Kirlian Photography".

*A single exception was work by D.G. Boyers and W. A. Tiller (J. Appl. Phys. Vol. 44, No. 7, July 197) in which some basic features of the CD photography experiment were investigated.

In the CD-photography experiment, a subject is photographed in a high-voltage field that produces a corona discharge about the subject. The recorded image is referred to as the corona signature. The characteristics of the recorded signature depend on the characteristics of the applied field, the recording medium, the position of the subject in the field, the environment of the subject (including the apparatus and atmosphere), and the physical (and to some extent the chemical) properties of the subject.

The applied field and the apparatus can be controlled sufficently to use the experiment to extract information about the subject. Those subject properties which we have found to have the greatest effect on corona signature are geometry, electrical resistivity, capacitance, and H_2O content.

In addition to making further investigations of the way in which corona signatures depend on basic experimental parameters, we have designed and performed three experiments that show how CD photography might be useful in the biological sciences. The experiments were examples of the use of CD photography to investigate

(1) In vivo, detailed structure and mechanisms

(2) Response to gross physiological changes in human subjects

(3) Physiological response to external and "psychological" stimuli.

These experiments were designed primarily to investigate the feasibility of CD photography as a tool, rather than to derive comprehensive information about a specific problem. Nevertheless, in one case (1 above) the method was so successful that we were

able to determine specific and useful information about skin hydration in human subjects.

In general, we have found strong evidence that CD photography may be useful as an analytical tool in two areas:

(1) Nondestructive testing of materials and certain types of assemblies and components, and

(2) Determining, in vivo, biological properties that depend on water content and/or impedance.

2.1 SPECIFIC RESULTS

2.1.1 Frequency-Dependency

We have designed and constructed a high-voltage CD power supply that allows us to vary pulse repetition rate, wave-shape, and pulse width. We have shown that, under certain conditions, corona-streamer range varies inversely with pulse repetition rate. This is the first reported data to support any investigation of the frequency dependency of the CD photography experiment. Because of time and funding limitations, we have not been able to conduct further investigations. However, we strongly recommend further examination of frequency responses as a prerequisite for the full understanding of CD photography.

2.1.2 The Influence of Moisture

We have found that the presence of even small amounts of moisture can reduce the extent of and even inhibit the formation of corona about a subject. Water appears to interact with the film surface to alter the electric

field about the subject to produce streamer curvature and inhibit streamer formation. When subjects are moist, the field on the reverse side of the film may be sufficiently strong to initiate corona there. This may be recorded as a fuzzy "secondary image" or as red to yellow corona when transparent film is used. The color occurs because the chromic layers of the film are exposed in reverse order. It is this effect that is responsible for many of the spectacular red flares seen in some photographs of human fingertips.

2.1.3 Skin Hydration

The moisture sensitivity of the CD photography has allowed us to design and conduct an experiment to investigate, in vivo, the hydration of human skin. CD photography is well suited for such an investigation, and further work along the lines we have begun should allow the development of an improved model of mass transfer across human skin.

We have shown, to date, that the skin acts as a selectively permeable membrane, which will pass hydrated Na^+ and Cl^- ions and water molecules. Water molecules appear to require less energy to pass through the membrane, and the rate of hydration depends on temperature and concentration gradients as predicted by thermodynamical considerations.

2.1.4 Physiological Investigations

We have shown that there is a corresondence between subject GSR and the corona signatures of human fingertips. We have also shown that hyperventilation will reduce the density of corona streamers. These effects appear, under the conditions of our experiments, to be due primarily to varaitions in the water content in the subject's skin.

2.1.5 Responses to External Stimuli

Experiments with several subjects have shown that stresses, such as a loud noise, will cause a reduction of streamer density in CD photographs. This appears, under the conditions of our experiments, to be a result of variations in moisture content of subject's skin.

2.2 APPARATUS

One of the major problems in the rigerous study of the corona signatures of subjects has been the development of an apparatus to apply a high-voltage electric field with characteristics that can be varied and controlled. The latest in the series of power supplies we have designed, constructed, and used overcomes many of the problems associated with previous equipment. With this apparatus we are able to vary voltage, waveform, pulse width, exposure, pulse repetition rate, polarity, pulse rise time, and several other parameters with accuracy and reproducibility. The apparatus is suited for the study of materials and human subjects.

2.3 APPLICATIONS

Evidence indicates that corona-discharge photography merits further investigations as an analytical tool for the biological and physical sciences. It may be useful for the nondestructive testing of metals, composites, and other materials; for the determination of water content in foods, coal, films, and dessicants; and for the testing of printed circuit boards and wiring for electrical continuity. In the biological sciences it may be useful for experiments based on moisture content such as those described in this report. The sensitivity to impedance and moisture may also be useful in the examination of cell structure and mass transfer through membranes.

All of these suggested applications are speculative. Yet it is reasonable to assume, based on our work to date, that they could be developed. Whether they will be sufficiently accurate and convenient to compete with existing techniques or offer capabilities not now available remains to be answered by further research, both basic and applied.

SECTION III

REVIEW OF CORONA-DISCHARGE PHOTOGRAPHY

3.0 GENERAL

In this section we briefly review corona-discharge photography and our work under all of the ARPA Order 2812. Our efforts have spanned a 1 1/4-year period, during which time we have been interested, primarily, in the basic physics of the experiment.

3.1 HISTORY

CD photography, as investigated by LTS, is an advanced version of the experiments reported by the Russian scientists Semyon and Valentine Kirlian in 1958. This work was first disclosed in the U.S. in the popular publication by Ostrander and Schroeder (1970), "Psychic Discoveries Behind the Iron Curtain". Because of the emphasis of the Russian work and the manner in which it was introduced, most of the early work in the U.S. was done by parapsychologists.

Our interest arose out of the novel feature of using photography to record a corona induced around a subject. We felt that the characteristics of the corona might be related in a useful way to the properties of the subject. In general, our researches have supported this hypothesis. At no time during our investigation have we found any evidence to support claims of connections of the electrical discharge with any parapsychological phenomenon. On the contrary, we have been able to show that many such claims have been due to faulty experimental procedure or misinterpretation of results.

3.2 THE CORONA-DISCHARGE PHOTOGRAPHY EXPERIMENT

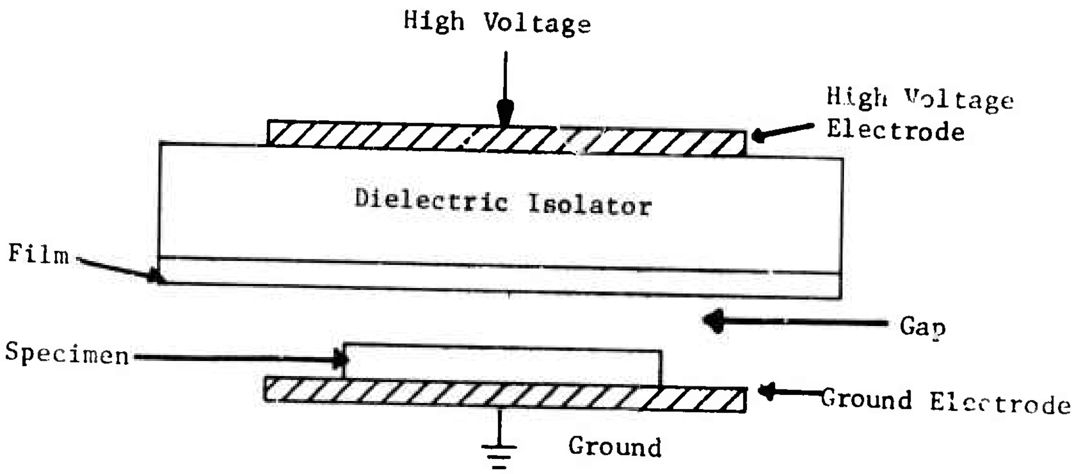
The basic corona-discharge photography experiment is performed as indicated in Figure 1. The applied voltage is on the order of 10,000 V, and the current across the electrodes is from 2 to 10 mA. The voltage signal may be dc, modulated dc, or ac. Pulse frequencies may vary up to 10 kHz. (Higher frequencies have been used, but we have yet to find any utility in employing very high-frequency voltages). Exposure times may vary from one 1/2-ms pulse up to several seconds. When two electrodes are used, the subject-to-ground electrode distance should be on the order of 0.2 to 5 mm.

Most any type of photographic film may be used to record the image, but the corona characteristics depend strongly on the film type used. Corona onset may be observed as spikes on the oscilloscope trace of the electrode voltage. Other corona-recording techniques may be used including electrostatic chart paper and CRT like devices.

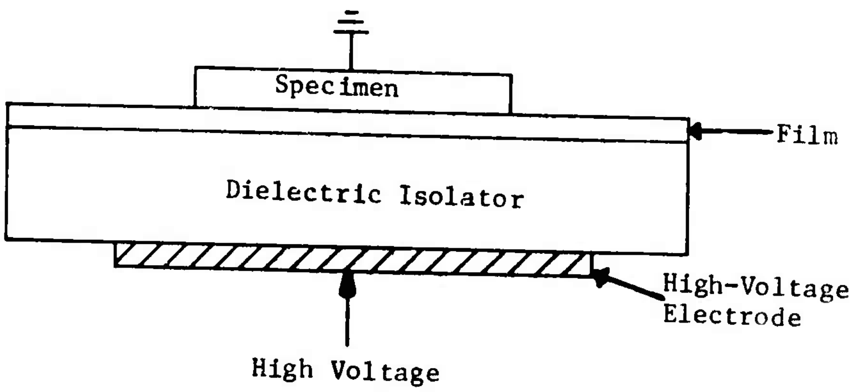
The dielectric insulator is used to prevent spark formation and current passage and to control the electric field. We have used plass plates, bakealite, and ceramics, from 0.15 to 0.65 cm thick.

3.3 Mechanism of the Corona Discharge

The term "corona-discharge" refers to the transfer of charge concentrations through a gaseous medium with the emission of light, initiated by a high voltage gradient. In the CD photography experiment, the onset of corona is governed by the voltage gradient from the electrode to ground, the gap between subject and electrode, and specimen properties. Other factors that are



(a) Two-Electrode Configuration



(b) One-Electrode Configuration

Figure 1. Basic Arrangements for CD Photography

important variables in CD photography experiments are the chemical composition of the gas, temperature, pressure, and electrode configuration.

At any given instant, there will be a small number of free electrons present in the air; these may be caused by ionization of gases due to background radiation and ultraviolet radiation. When a voltage gradient is imposed, these electrons are accelerated towards the anode. If the gradient is large enough, the electrons will ionize (remove electrons from) molecules in the gas. These ionized electrons will, in turn, be accelerated, collide with gas molecules, ionize further electrons, etc. Thus a cascading effect occurs, and large numbers of free electrons are produced. In general, electrons are created by ionizing collisions, photoionization of gas, ion bombardment of the cathode, or by photoionization of the cathode. Electrons are captured by the electrodes, the surrounding atmosphere, or ionized and unionized gas species.

When an accelerated electron collides with a molecule, it may not remove any electron but only raise electrons to a higher energy state. The high-energy state has a short lifetime, and the electron will drop back to its ground state with the emission of electromagnetic energy. In air, this energy is visible or ultraviolet radiation, and is the source of some of the light emitted. The emitted radiation may be reabsorbed by other molecules, resulting in photoionization or other excited (high-energy) electron states.

When the discharge occurs in air, the spectral distribution (and thus color) of the discharge is determined primarily by the emission spectra of nitrogen and oxygen. These are mostly in the blue-visible and ultraviolet regions of the spectrum.

In a classical high-voltage point/plane-shaped-ground electrode experiment, corona formation will depend, among other things, on the relative polarity of the electrodes. When the high-voltage electrode is positive, the discharge is initiated within the gap by electrons accelerated towards the positive electrode. The ionization procedes towards the anode (positive electrode), and creates a positive-ion cloud that extends into the gap and away from the electrode. As this positive cloud moves toward the cathode, the streamer channels observed in CD-photography are formed. A dense collection of filaments which extend only about 1 or 2 cm from the anode may be observed as a steady, glow-like corona.

When the high-voltage point electrode is negative, a fluctuating glow region, called the Trichel pulse region, forms about the point (cathode). In this case the positive ions are attracted to the high-voltage point and the visible discharge is localized there. At sufficiently high fields (voltage gradients) filaments will extend out from the glow region.

In the CD photography experiment, the high-voltage electrode is a plane, rather than a point. The result is that a fairly uniform field is created across the electrode gap.

When a specimen is placed in the field, corners and other high-curvature parts of the specimen act as high-voltage points, to initiate corona discharge. In the single-electrode case, the field is not as uniform, but the specimen plays a similar role.

Both positive and negative corona occur in CD photography. These can be observed from the corona characteristics and as positive and negative corona spikes on an oscilloscope.

3.4 BREAKDOWN VOLTAGES

Breakdown or corona-onset occurs as a sudden rise in current across the electrode, accompanied by a luminous discharge. This occurs when the electric field is strong enough that more electrons are generated in the gap than are lost (the Townsend condition). Breakdown depends on the local field strength (the voltage gradient) rather than the total voltage drop. Thus it depends on gap width, insulating materials (including film) present, and subject geometry and permittivity. Breakdown voltages in CD photography are fairly close to those reported in point-to-plane experiments. Breakdown voltage also depends on the rise time of the applied voltage. The longer the rise time, the lower the onset volta

We have also observed a "conditioning" effect in breakdown voltage values. It appears that during a CD photography, a static charge forms on the surface of the sample or film to raise its potential. Thus a second discharge initiated shortly after the first will require a smaller applied voltage.

3.5 CHARACTERISTICS OF CORONA SIGNATURES

Three general types of corona are observed most often.

(1) positive streamers

(2) positive glow

(3) negative glow

The corona generally follow the geometric outline of the specimen and are initiated at points of high curvature (e.g. edges, holes, scratches, and corners). Streamers radiate outward from the specimen. Glow corona form about the specimen, but do not extend as far as the streamers.

The color of the corona is blue. Photographs of other colors can be obtained, but these are the result of secondary photographic images, and are not the actual color of the corona.

"Secondary" images refer to corona formed on the side of the film opposite the specimen. In certain cases the field strength on the reverse side of the film is strong enough to initiate corona. Unless the film has an opaque packing, it will be exposed by such secondary corona. Because the light passes through the film in reverse order, redish-orange images result, rather than the actual blue of the corona.

3.6 OTHER SOURCES OF FILM EXPOSURE

Other sources of film exposure may also occur, but only under special conditions or to a minor degree. There may be some exposure due to electron bombardment of the film. Many types of film are exposed by pressure.

Under a voltage gradient, there may be an electrolytic chemical transfer from the subject to the film. It will yield

a color that depends on the particular chemical species. In some cases there may be vaporization and ionization of chemicals in the subject which yield corona characteristic of the vaporized species.

3.7 FACTORS AFFECTING CORONA IMAGE

Three general types of factors affect the corona signatures of a specimen: (1) the nature of the applied field, (2) the properties of the specimen, and (3) the particular experimental arrangement.

3.7.1 Applied Field Characteristics

(a) Voltage - Intensity and streamer range increase as the applied voltage is raised above the breakdown value.

(b) Polarity - When the applied voltage is rectified positive, the corona consists of streamers and glow about the subject. When the voltage is negative, mostly spot and glow corona occur.

(c) Pulse repetition rate - As the pulse repetition rate increases, streamer length decreases, and the extent of totally exposed film about the periphery of the subject decreases (after the first pulse).

(d) Exposure time (number of pulses) - Each pulse creates a complete corona formation event; thus as the number of pulses increases (greater exposure time), the number of streamers and corona density increase. Streamer lengths decrease sharply after the initial pulse, gradually increasing with subsequent pulses

until they equal the initial length after long exposure time.

(e) Voltage waveform - In general, the slower the voltage rise time, the shorter the streamer range is.

3.7.2 Specimen Properties

(a) Geometry - The general outline and particular site of corona formation follow the edges, corners and other high-curvature points of the specimen.

(b) Impedance - A decrease in streamer length. Thus, subject permitivity and resistivity play a part in corona signature patterns.

(c) Potential of specimen - Some experiments have indicated that the potential of the specimen relative to ground may affect corona. The sensitivity to relative potentials across a specimen is not known.

(d) Chemical/Physical specimen of properties - In addition to the resistivity and permitivity of the specimen, other chemical and physical properties may affect the corona. Moisture influences streamer length and causes streamer curvature indirectly via interaction with the film. Other properties such as ionization potentials may have some minor affects, but these have not been determined. Also, the transfer of chemical species under an electrical field may cause color exposure of film depending on the particular species.

3.7.3 Experimental Procedure

(a) Recording medium - The recording medium plays an important role in determining corona characteristics. Opaque-backed film will not generally show colors other than blue, nor will secondary corona be observed. The extent of variations in corona, in response to variations of specimen or field parameters, will also depend on film type. Electrostatic paper images of corona will also differ somewhat from the optical images.

(b) Dielectric isolator - The dielectric constant and the thickness of the dielectric isolator will shape the applied field. The dielectric can be selected to increase the horizontal field component and increase streamer range.

(c) Gap distance - Specimens in contact with the film give considerable flairing of streamers, due to the initial field direction and interaction with the film. When there is a gap between the film and the specimen, more information is obtained on details within the specimen outline. For appreciable gaps, the streamer extent is reduced.

3.8 COMPLEX SUBJECTS

Experiments with complex subjects such as human fingers have shown that sufficient control may be exercised to allow the observation of a single subject parameter. Those parameters with which we have had the most success to date are geometry and moisture content. These, of course, may be related directly to more complex subject properties.

For instance, by measuring moisture content of human fingers, we have been able to show correlations between CD photographs and the psychological stimuli.

SECTION IV

EXPERIMENTAL EFFORTS DURING PHASE III

4.0 GENERAL

The experimental work during this final phase included the areas:

1. Improvement of apparatus
2. The influence of moisture
3. Studies of characteristics of corona signatures
4. Studies of skin hydration
5. Effects of external stimuli

The original research plan, as proposed, included a Phase IV which would have been devoted to further investigation of corona discharge (CD) experiments that are suggestive of practical application. The efforts of this phase were to have been devoted to: (1) the design and construction of apparatus for use in Phase IV, and (2) the identification of, and preliminary work on, areas for further experimental work. The emphasis was to be on biological/human subjects.

Despite the fact that the option for Phase IV was not exercised we have followed the proposed research plan for Phase III. The emphasis has, however, been somewhat different than it might have been had further work been planned. Less emphasis has been placed on the development of apparatus, and more on the study of the corona of human fingers and possible applications. As a result we are able to make a better estimate of the future of CD photography as a practical tool in the biological and physical sciences.

In this section we describe and discuss all the experimental work of Phase III, except the design and construction of the apparatus; it is discussed in Section V.

4.1 STUDIES OF CHARACTERISTICS OF CORONA SIGNATURES

Throughout the program, a substantial portion of our work has been devoted to interpretation of the details of corona signatures. During this phase, we investigated (1) the influence of moisture, (2) the influence of pulse repetition rate, (3) factors affecting streamer range, and (4) secondary images.

4.1.1 The Influence of Moisture

- Background -

We had previously*reported that two effects are observed with wet subjects.

1. Some streamers are curved

2. There is a marked reduction in streamer formation

Streamer curvature does not occur and there is less reduction in streamer formation when electrostatic paper is used as the recording medium or when a thin film of mylar is placed between the wet subject and the film. It is therefore reasonable to hypothesize that the curvature and diminished corona activity are related to an interaction of water with the surface of the film.

*Logical Technical Services Corp, Final Technical Report Phase II, Investigations Into the Reliability of Electrophotography, Sec. 4.3

- Experimental -

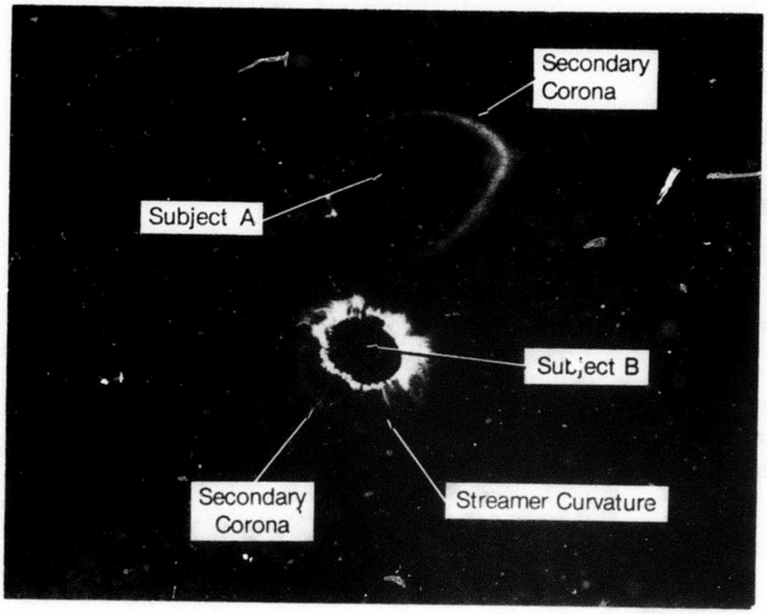
CD photographs of fingertips show a correlation with moisture on the finger as measured by sweat count and by galvanic skin response techniques. Sweat count is a technique of obtaining a rough comparision of the amount of moisture on the finger tips of subjects. The finger is coated with a mixture of polyvinyl formal, ethylene dichloride, and butyl phthalate after the method of Sutarman and Thomson*.

The film drys in about one minute. The hardened film is removed from the finger tip and examined under a 23X microscope. Sweat-active pore sites appear as discontinuities or holes in the film; the number of sites corresponds to the number of sweat-active pores, and their size corresponds to the degree of activity.

In general, streamer activity varies inversely with sweat count. For example, Figure 2 is a CD photograph of the fingertips of two subjects. Subject A had a high sweat count and subject B had a low sweat count. It can be seen that there is virtually no streamer activity around the finger of subject A, while subject B exhibits considerable corona and streamer activity. That corona that does appear around the finger of A is what we have called "secondary" corona. The formation of secondary corona is discussed

**Sutarman, M. L. and Thomson, M. L. "A New Technique for Enumgrating Active Sweat Glands in Man' J. Physiol. (London) 117, 52, (1952)

EXPERIMENTAL CONDITIONS:
Supply: LTS 001
Waveform: AC, See Figure 18
Repitition Rate: 50 pps
Exposure: 24 pulses
Peak Voltage: -18 kV
Isolator: 1/4 in. glass plate
Film: Polaroid 55
Subject: Index Fingers, right hands of LTS Subjects A and B



Notes: (a) Subject 3 had a higher sweat count than Subject 1.
(b) The film used has a transparent backing.

Figure 2. Comparative Finger Tip Corona

later, but in the context of this discussion it should be noted that the secondary corona occurs on the back of the film. If film with an opaque backing had been used, this corona would not have exposed the emulsion on the front of the film, and there would have been little or no corona photographed around the finger of subject A.

Experiments in which measurements of GSR were taken also support the observation of water-induced streamer inhibition. When GSR measurements are low (on the order of 10 kilohms), sweat activity as determined by sweat count is high. When GSR measurements are high (on the order of 100 kilohms) the sweat count is found to be low.

The correlation between the density of corona/streamers and GSR holds over a limited range of GSR values. Relatively high GSR's are independent of sweat count. Also, the correlation of GSR with sweat-count is better for variations in one individual than across different individuals over a limited range.

In a series of experiments in which the corona activity of subject fingertips are compared with GSR readings, the density of corona and streamer activity correlate with GSR over the range that sweat count correlates with GSR; i.e., subjects with high GSR (and thus "dry" skin) exhibit extensive corona with marked streamer activity; under identical conditions, subjects with low GSR (and thus "moist" skin) exhibit little corona or streamer activity.

CD photographs of a finger replica (see Section V Experimental Techniques and Apparatus) covered with wetted (distilled H_2O) filter paper show a marked decrease in streamer activity compared to CD photographs of dry replicas. The same effect is observed with saline solutions and tap water.

In one experiment, a finger replica was photographed with dry filter paper, then with wet filter paper, then photographed again with dry filter paper. As expected, the corona signatures of the wetted replica were diminished and showed more streamer curvature than those of the dry replica. However, the third CD photograph in the sequence - covered with fresh dry filter paper - also exhibited streamer curvature and diminished corona, although to a lesser extent than the wetted replica. Apparently, the moisture absorbed by the wooden replica when covered with wet paper is sufficient to modulate the corona pattern.

Another effect, noticed with the CD photographs of human fingers, was an increase in the corona activity of subsequent photographs of a subject when taken less than one minute after an initial photograph. This suggests that the corona discharge "drys" the subject somewhat.

- Discussion -

Wet subjects produce diminished CD photographs with increased streamer curvature, but only when there is direct contact with the film. This suggests that the observed effect is due to an interaction between the film and H_2O. A corona

discharge "drys" a specimen, and water absorbed in the wooden finger replica affected the corona signature. It is apparent that there is physical transport of water molecules during the corona discharge.

A tentative mechanism can be proposed to explain these effects of moisture. If moisture is absorbed in the film gel close to the subject, ionization and ion mobility in the moistened film region would be expected to increase. A rough indication of the extent of this moistened area may be obtained by pressing a finger on a clean glass plate. Moisture condensation can be observed around the finger at a distance close to that observed for the secondary image in Figure 2.

The increased ionization and ion mobility in the film gel will increase the conductivity of the gel in that region, and its potential will approach that of the fingertip (Ground). This situation for a positively charged finger is shown in Figure 3.

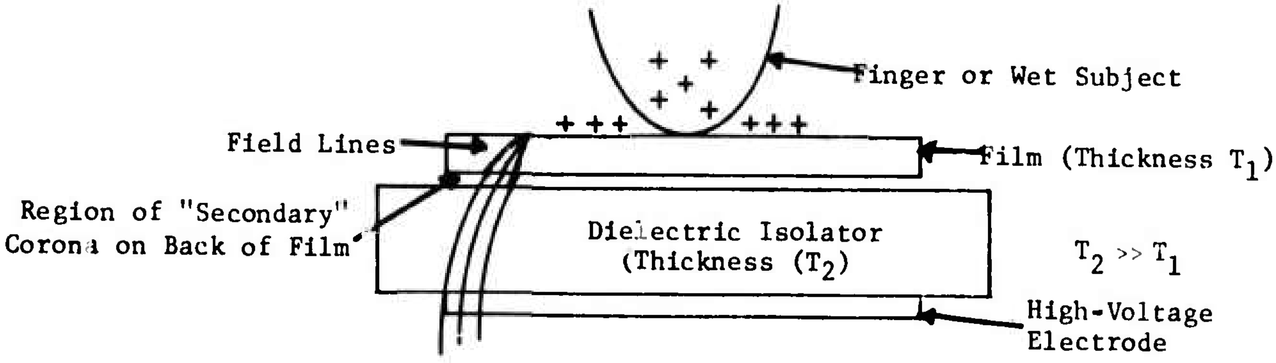


Figure 3. Moist Subject

The electric charge and reduced potential in the region around the subject creates a low field region in which corona are not formed. The boundry of this charged, moist region is a relatively high-field area. This field may be strong at the back of the film and corona may occur there. Because of the field direction and because there is limited air space for the streamers to propagate through, they tend to be short . Since the corona light must pass through the transparent film backing before exposing the emulsion, the secondary image is usually fuzzier or more diffuse than the images of primary corona occurring on the front of the film.

Primary corona are sometimes observed at the edge of the charged moist region, but less frequently. This is probably because there are few sharp points at the edge of the "moist" region and the field is directed downwards.

The curvature characteristic of streamers occurring around the moist area can be explained in terms of a model of the streamer propagation. The streamer head is a region with a net positive charge and from which high energy photons are emitted. This energy will photoionize other molecules around the head, releasing electrons. These electrons will be attracted to two regions: the streamer head and the positively charged region of the film. This results in higher ionization within the head and on the side adjacent to the positive charge region. Thus there is a force vector acting on the streamer head and pulling it toward the boundry of the moist region. There

are also the repulsive forces between the positive streamer head and the positive moist region, and the resultant is a curved streamer propagation path, traversing the region where there is a sharp change in surface charge concentration.

4.1.2 Secondary Corona

- Background -

By "secondary" corona we refer to corona believed to be formed on the back of transparent film and resulting in an exposure of the film surface. We have discussed these when examining the effects of moisture.

- Experimental -

The finger of subject A in Figure 2 is surrounded by secondary corona. The corona signature of subject B in the same photograph also includes a region of secondary corona. In general, as in these two cases, secondary corona appear where there is little streamer activity. This is not, however, a universal result, and in some cases there appear to be secondary corona beneath regions of streamer activity.

Secondary corona are observed only with film that is transparent. With opaque-backed film such as Polaroid 52, we have not observed secondary corona.

In some cases we have observed streamers originating from an area of secondary corona; these are assumed to be "primary" streamers occurring on the front surface of the film. The primary and secondary corona are most distinctly

differentiated when using colored film.

The characteristic color of corona is air is blue. We have produced photographs with red to yellow corona images caused by blue corona with unfiltered UV content occurring on the back of the film. This light passes through the color filters in the film in reverse order, exposing first the red, then green, then blue emulsions, to yield red, orange, or yellow rather than blue images. Violet has been obtained from exposure of both red and blue emulsions (both primary and secondary corona).

- Discussion -

The formation of the high-field region on the back of the film and the characteristics of the secondary corona are discussed in Section 4.1.1. "The Influence of Moisture". These corona are most often observed with moist subjects which create an corona inhibiting region on the front of the film and a high-field region on the back.

A word is appropriate here about photographs taken by amateurs and others in which blue images are associated with a subject in the "normal" state, and red/orange/ yellow streamers in some psychic or otherwise heightened state. The most likely explanation for these corona is that in the "heightened" state the subject is changing skin moisture content and this results in the formation of red secondary corona.

4.1.2 Pulse Repetition Rate

- Background -

One area of interest in studying the formation of CD images is the effect of the frequency of the applied voltage. Because of the difficulty of constructing variable-frequency apparatus at the high voltages used in the CD experiment, little work has been done in this area. We have examined the effects of variations in the pulse repetition rate; such experiments yield information useful in determining frequency effects.

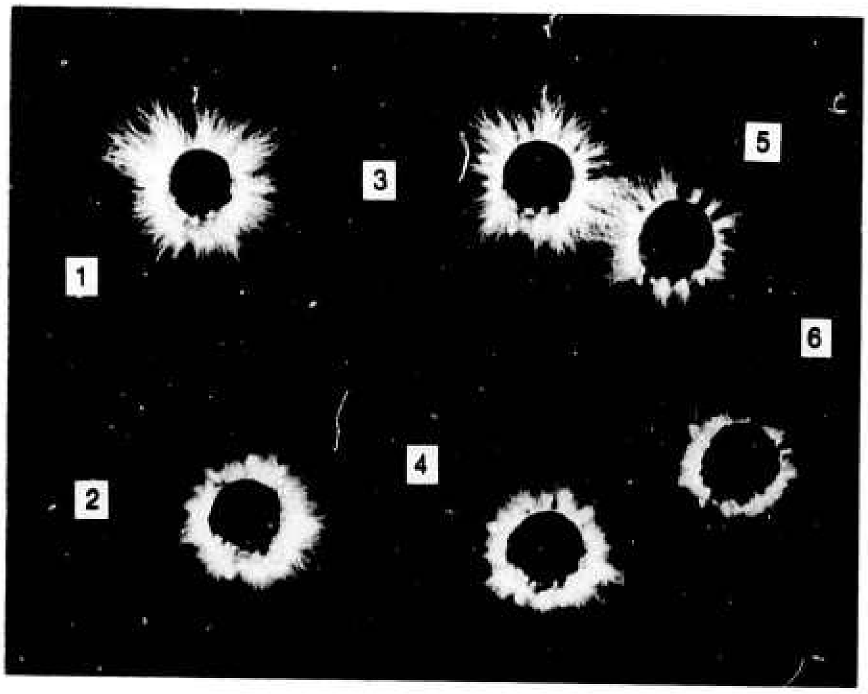
- Experimental -

Figure 6 shows the corona of a finger replica taken at three pulse repetition rates. As the repetition rate increases there is a decrease in streamer length and density. The length of the longest streamers (formed upon the first pulse) remains about the same, but the range of succeeding streamers decreases, and the extent of the totaly exposed area around the periphery of the subject decreases. In most cases it is observed that the average streamer length decreases.

- Discussion -

One possible explanation of the reduction in streamer activity and length upon an increase in pulse repetition rate assumes that a charge builds upon the film surface with each pulse. The corona and streamers occurring at the first pulse will not depend on the pulse repetition rate, as there is no preceding pulse to affect them.

EXPERIMENT CONDITIONS:
Supply: LTS 001
Waveform: AC, See Figure 18
Repitition Rate: As shown
Exposure: 20 pulses
Peak Voltage: -18 kV
Isolator: 1/4 in. glass plate
Temp: 23 C
R.H.: 50%
Subjects: Finger Replica No. 1
Film: Polaroid 52



Pulse Repitition Rates: 5.5 pps for 1 and 2
14.3 pps for 3 and 4
50 pps for 5 and 6

Note: 1-mil mylar isolator used with 2, 4, and 6.

Figure 6. Variations in Pulse Repitition Rates

Therefore, the length of these first pulse streamers should be the same for all pulse rates.

The first pulse may build up a static negative charge on the film. This charge will attract the positive streamer head, restricting its radial extent. The amount of charge on the film will depend on how much time there is between pulses for the charge to leak off. Thus faster pulse repetition rates would mean more negative charge, and shorter range for streamers occurring after the first pulse.

Confirmation of this proposed mechanism would require some knowledge of the amount of charge on the film and the time-rate of decay. But, within these restrictions it is consistent with observations.

After a sufficiently long period of time, the streamer length appears to approach that of the first strike. This may be occurring because the increased corona activity neutralizes the charge buildup on the film. Another relevant factor may be the accumulation of ozone in the electrode region.

4.1.3 Other Factors Affecting Streamer Range

- Background-

Several other factors reflect the streamer range, and further studies were made of these during this phase. These include film type, subject impedance, and the type of dielectric isolator used.

- Experimental and Discussion -

We have previously reported that the impedance of the subject affects the corona pattern. In Figure 7, we have

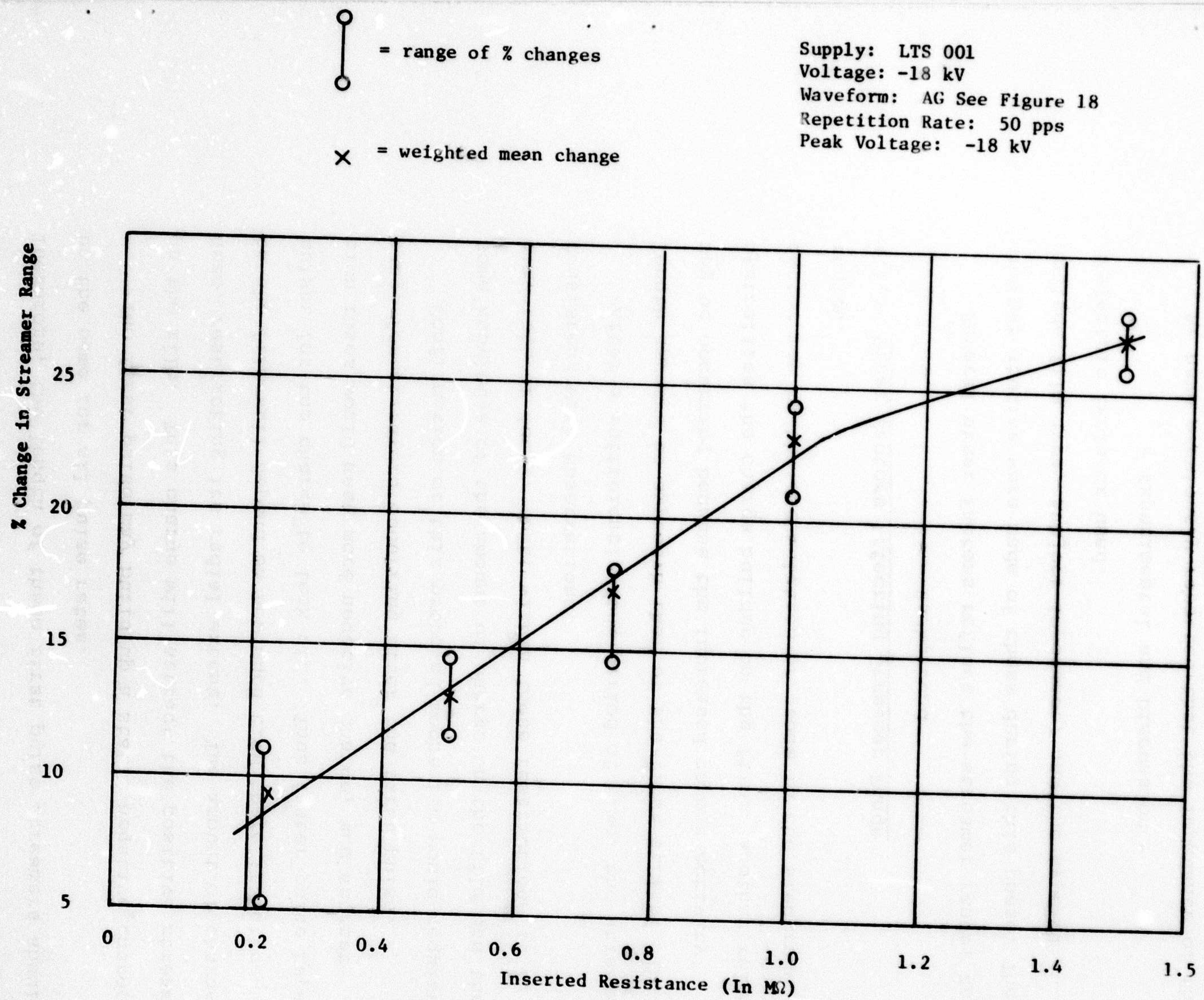


Figure 7. Change in Streamer Length Vs Resistance

plotted the change in streamer length against the value of resistance inserted between the subject and ground. With the LTS 001 supply, the percent change was found to vary linearly up to about 1 megohm, where it was from 10 to 20 percent. With the LTS 100 supply the change is about 10% at 1 megohm. However, with experiments with human subjects with the LTS 001 supply, at a frequency of about 4 kHz (rise time 64 μs) no significant change in streamer length was noted with a 300 kilohm variation in subject GSR.

An attempt was made to employ a dielectric isolator of very high dielectric constant. A sample of ceramic material was obtained from Corning Glass Corp. with a dielectric constant around 7000. It was hoped that the use of this material would allow a lower electrode voltage to be used since the smaller voltage drop across the dielectric would mean a larger voltage drop across the specimen.

However, when the high-dielectric-constant material is used the corona streamers are very short. This is probably due to the severe mismatch of dielectric constants between the boundry of the film and the isolator. This discontinuity tends to draw the field lines in towards the specimen, thus confining the radial extent of streamer propagation.

It has also been observed that streamer propagation varies somewhat with film type. In general, variations in streamer length are more pronounced for Polaroid Type 55 film than for Polaroid Type 52. This appears to be true for the effects of moisture and pulse-repetition variations.

4.2 STUDIES OF BIOLOGICAL, PHYSIOLOGICAL, AND PSYCHOLOGICAL PARAMETERS

Three groups of experiments were performed as prototypes to determine the applicability of CD photography to studies of living systems. One experiment, an example of in vivo biological studies, was to determine the absorption of moisture by the human skin. A second experiment was conducted to relate physiological changes to CD photographs. Finally a series of experiments were conducted to relate responses to external stimuli and psychological states to changes in CD photographs.

4.2.1 Skin Hydration

- Background -

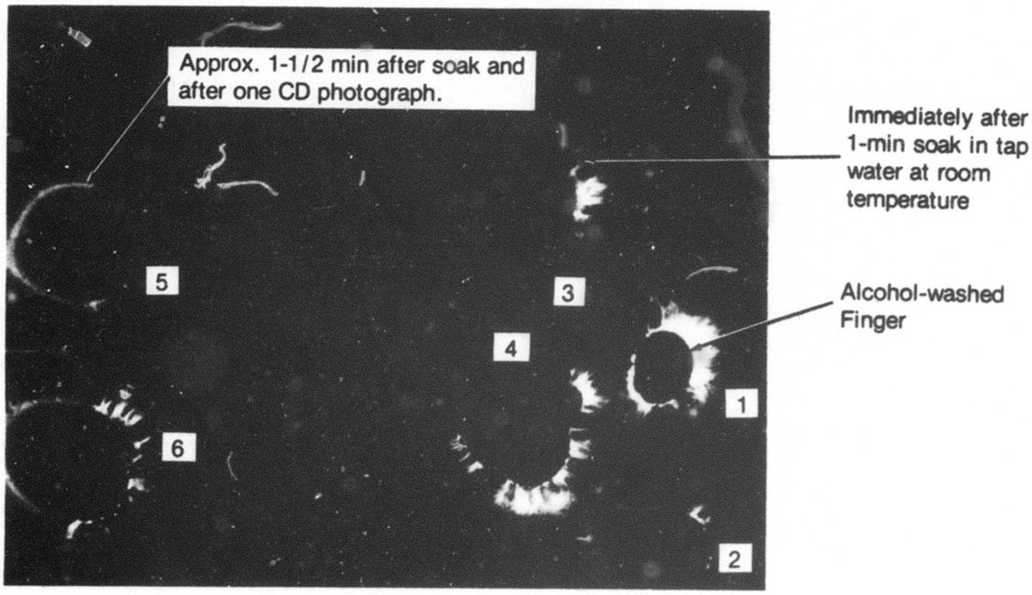
Because CD photographs are particularly sensitive to the amount of moisture on a subject's skin, it appears reasonable to use CD photography to investigate skin hydration. It has been suggested* that the skin acts as a selectively permeable membrane, and that absorption of water depends on temperature and the concentration of solutes in the absorbed water.

- Experimental -

Further initial experiments were performed to establish the relation between skin moisture and corona signatures. Figure 8 is a CD photograph of the index and middle fingers of the same subject. Three exposures

*Buether, K. J. K. "Diffusion of Liquid Water Through the Skin" J. App. Physio, 1959. 14, 261-268

EXPERIMENTAL CONDITIONS:
Supply: LTS 001
Waveform: AC, See Figure 18
Repitition Rate: 50 pps
Exposure: 24 pulses
Peak Voltage: -18 kV
Isolator: 1/4 in. glass plate
Subject: Index and Middle Finger of LTS Subject A
Film: Polaroid 55



Notes: (a) Images 2, 4, 6, are of the control finger, which was untreated throughout; 1, 3, 5 are images of the test finger. Exposures were taken in the order 1 & 2, 3 & 4, then, 5 & 6.

Figure 8. Effects of Hydration on Fingertip Corona

were made. In the first exposure, one finger was washed with alcohol to remove water from the skin. The alcohol-dried finger exhibited a more pronounced corona. For the second pair of photographs, the alcohol-dried finger was soaked in distilled water for 1 min. The corona around the soaked finger is markedly reduced when compared to the same finger dry.

The corona around the other (control) finger is more pronounced and has more streamers than the first photograph. This effect is due to the drying action of the initial corona.

The third pair of CD photographs were taken 1 min. after the second pair; the fingers were not treated in any way. The drying action of the corona discharge on the water-soaked finger was not sufficient to reinitiate substantial corona.

Next a series of experiments were performed to examine the moisture absorption as a function of temperature.

A solution of 20% by weight (4.2N) NaCl solution was prepared. Three photographs were taken of the index and middle fingers of the subject. For the first photograph, both fingers were washed in alcohol to remove moisture. Before the second photograph, one finger was soaked in the 20% NaCl solution, and the other was soaked in distilled water, both for 1 min. Both fingers were wiped dry with paper toweling, and the second photograph was taken. After a waiting period of 1 min., both fingers were photographed

again. Three such series of photographs were taken at approximately 10^{o} C, 23^{o} C, and 35^{o} C. The experiment was performed on three subjects. Figures 9, 10, and 11 are the results for one of the subjects. The CD photographs for the other two were similar.

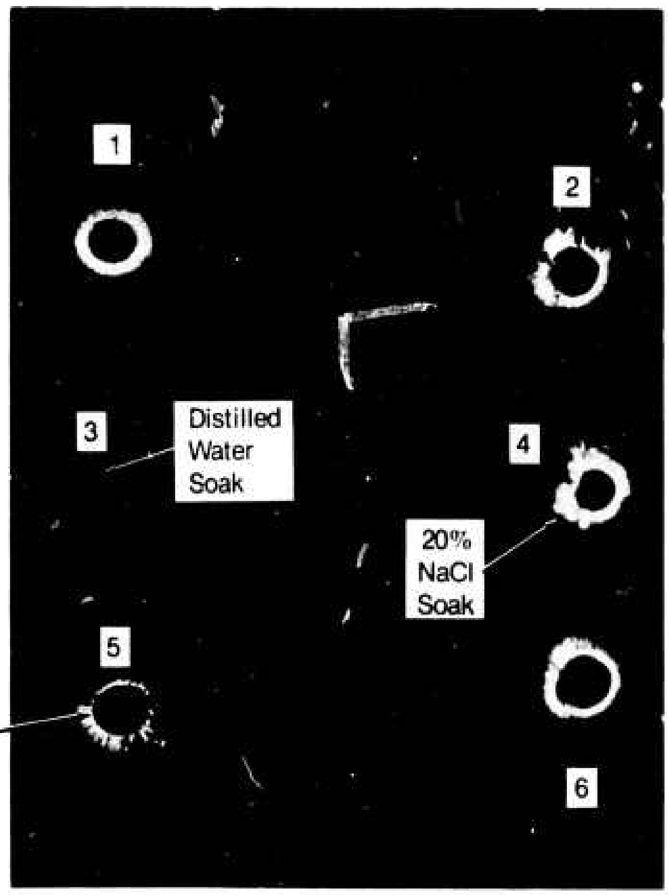
- Discussion -

At the low temperature, (the photographs in Figure 9) the presence of corona for the NaCl-soaked finger and absence of corona for the distilled-water soaked finger indicate that mositure was absorbed by the distilled water finger, but not by NaCl soaked finger.

The room-temperature photograph (Figure 10) indicates that moisture was again absorbed by the distilled-water soaked finger. A slight reduction in corona around the NaCl-soaked finger indiacates that some water was absorbed, but not as much as for the distilled-water soaked finger.

The high-temperature photograph (Figure 11) indicates that water was absorbed by both fingers. Some estimate of the relative amount of water absorbed at the three temperatures may be made by examining the third exposure for all three cases. For the distilled water photograph the amount of corona around the third exposure decreases slightly from the cold- to the high-temperature case. This indicates that at higher water temperatures the following corona drying is less effective and therefore more water is absorbed by the finger. Supporting this also, is the total absence of corona image for the second exposure,

EXPERIMENTAL CONDITIONS:
Supply: LTS 100
Waveform: Modulated DC, See Figure 20
Repitition Rate: 50 pps
Voltage Rise Time: 300 μs
Duty Cycle: 25%
Exposure: 20 pulses
Peak Voltage: -11 kV
Film: Polaroid 55
Subject: Index and Middle Fingers of LTS Subject D
R.H.: 53%
R.T.: 23° C



1 and 2, after alcohol wash

3 and 4, after 1-min soak and wipe dry

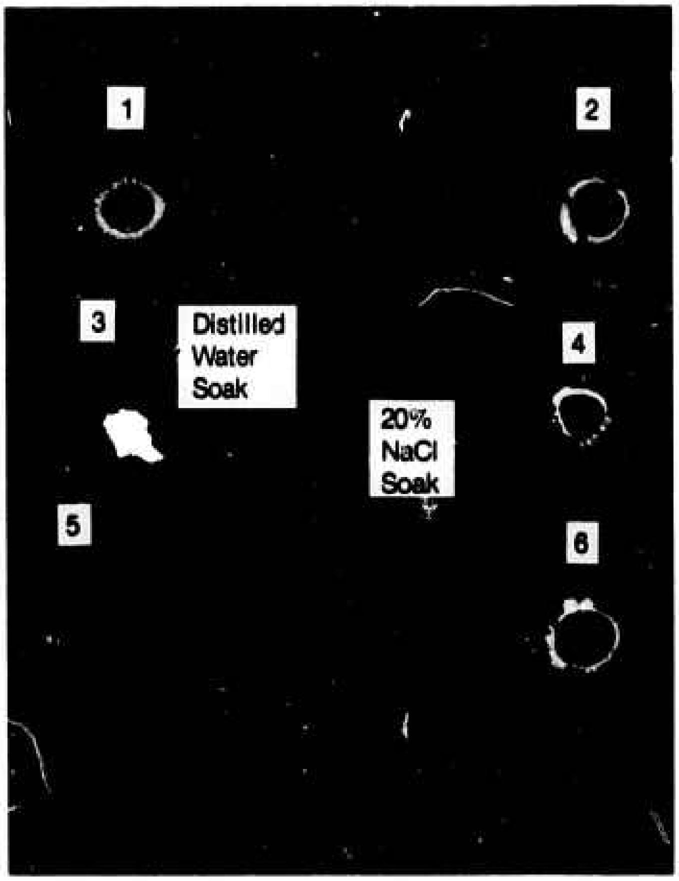
5 and 6, 1 min after 3 and 4, no treatment

Streamer Curavture

Notes: (a) soaking solutions were at 8 C. (b) Saline solution was 20% NaCl by weight in distilled water.

Figure 9. Skin-Hydration Experiment: Low Temperature

EXPERIMENTAL CONDITIONS:
Same as Figure 9.



1 and 2, after
alcohol wash

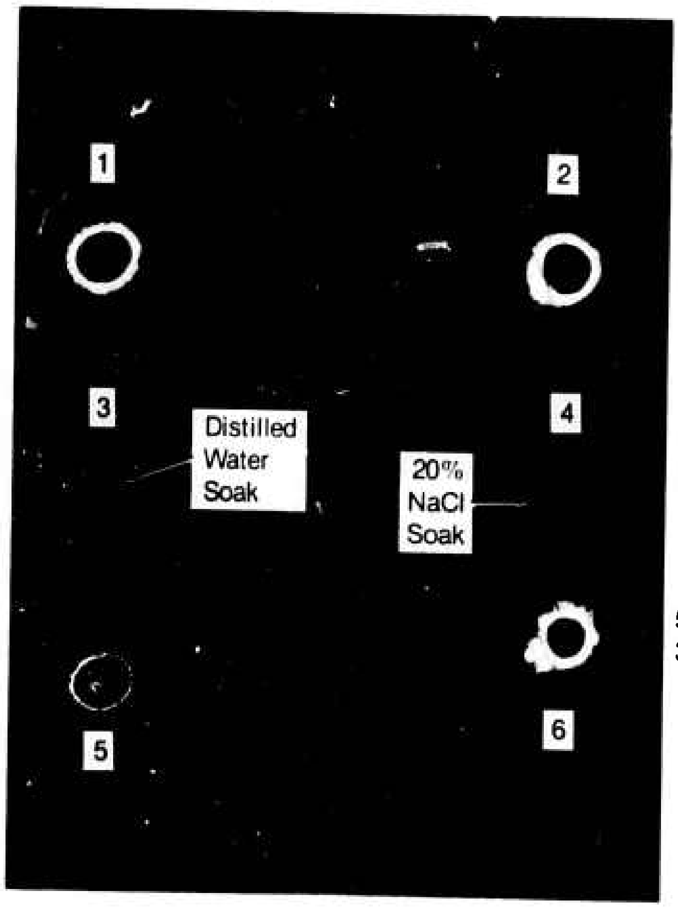
3 and 4, after
1-min soak and
wipe dry

5 and 6, 1 min after
3 and 4, no
treatment.

Note: Soaking Solutions were at 22.7 C

Figure 10. Skin-Hydration Experiment: Room Temperature

EXPERIMENTAL CONDITIONS:
Same as Figure 9.



1 and 2, after alcohol wash

3 and 4, after 1-min soak and wipe dry

5 and 6, 1 min after 3 and no treatment

Note: Soaking Solutions were at 35.5 C

Figure 11. Skin-Hydration Experiment: High Temperature

after high-temperature soak. For the room-temperature and high-temperature soaks, the third image for the NaCl-soaked finger exhibits more corona than the image of the distilled-water soaked finger, further indicating that the distilled-water soaked finger absorbed more water.

The conclusions to be drawn from these experiments are:

1. Moisture absorption by the skin increases with increasing temperature

2. Moisture absorption by the skin decreases in saline solution.

These conclusions are consistent with a model in which the skin is treated as a selectively permeable membrane. The tendency of water to move through the membrane depends on the relative chemical potentials of the solutions internal and external to the membrane. The chemical potential is dependent on the temperature of the solutions and the concentration of solutes in each.

With the approximation that the solution internal to the membrane is at body temperature ($\approx 37^{\circ}$ C), temperature tends to make the chemical potential internal to the membrane greater than the external potential, except for the high-temperature case for which the temperatures are about the same.

For the saline solution, the NaCl concentration of the saline solution (4.2 N) tends to make the chemical potential of the external solution greater than the internal solution (0.1 N NaCl). For the distilled

water case, the concentration tends to make the internal-solution chemical potential greater.

The system will tend to equalize the chemical potentials on the two sides of the membrane. Aside from temperature changes. two mechanisms are of interest: migration of water molecules, and migration of hydrated Na^+ and Cl^- ions. Strictly speaking, the Na^+ and Cl^- ions will not diffuse in the same way (the Donnan effect), but for the purpose of the very rough model used here they will be assumed to behave identically. The water molecules will have a higher mobility than the hydrated Na^+ and Cl^- species, and will thus pass through the membrane more easily. Thus at the low temperature, when the external solution is 4.2 N NaCl, water will tend to pass from internal to external and hydrated ions will pass from external to internal. The lower mobility of the hydrated ions will inhibit their transfer, opposing skin hydration. Also, the higher internal temperature raises the internal chemical potential, reducing the forces across the membrane. For the distilled water-case, hydrated ions internal to the membrane will tend to move out, and water molecules will move in. Because of their greater mobility the water molecules will tend to move more. In this case the temperature and concentration gradients work together, to both raise the internal potential and lower the external potential.

For the room temperature case, the situation is similar, except the temperature difference is smaller and has less effect on the potentials. Thus there will be more hydration during the external-saline solution soak. In the high temperature case, the internal and external solutions are at approximately the same temperature, and hydration will be predominantly concentration dependent. Thus there will be significant hydration for both the distilled-water and saline-solution soaks.

The other factor affecting the hydration will be diffusion rates. As mentioned, these depend on the species mobility. Generally for a given concentration gradient, diffusion rates will increase with increasing temperatures. Thus it is expected that hydration will increase with increased temperature, as shown by the experiments. The mechanism for hydration probably involves imbibitation by the stratum corneum, which may absorb up to 2000% of its dry weight in water (Buettner, 1959).

4.4.2 Hyperventilation and GSR

- Background -

In an effort to investigate the use of CD photography is measuring gross physiological changes in subjects two types of data were obtained: CD photographs as a function of GSR measurements and (2) CD photographs before and after hyperventilation.

- Experimental -

The relationship between GSR readings and CD photographs is discontinuous. There is positive correlation at low

(10 KΩ) and high (100 KΩ) GSR readings. At low readings the corona are of low density, and at high readings they are more dense. At intermediate values, corona cannot be predicted by GSR levels.

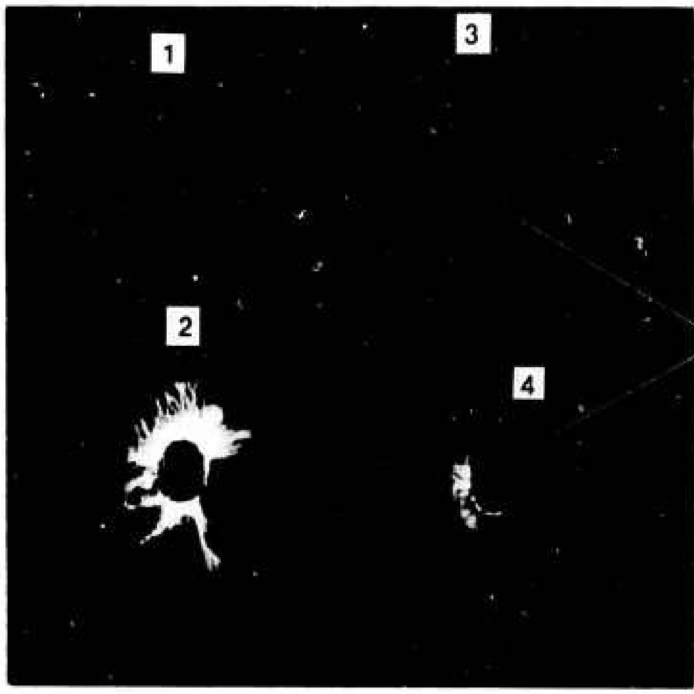
The index (alcohol washed) finger and middle (not washed) finger of six subjects were CD photographed before and after hyperventilation. First the pair of fingers were photographed and the subject hyperventilated for 1 1/2 min, breathing at 30 cycles/min. A CD photograph was then taken. After a 1 min rest, a third CD photograph was taken.

Figure 12 is the result of one hyperventilation experment. In the first exposure the alcohol-washed finger exhibited substantial corona, the unwashed finger exhibited none. In the second (after hyperventilation) exposure, the alcohol-washed finger exhibited corona that was reduced, compared to the first exposure. In the third exposure, both fingers exhibited corona.

Of the six subjects tested, five exhibited similar results. The sixth subject's corona signature after hyperventilation was not reduced.

GSR is also related to hyperventilation; hyperventilation causes an initial drop in GSR followed by a return to baseline. If the intial GSR (before hyperventilation) was relatively low, the deep breathing substantially reduced corona. If the initial GSR was relatively high, hyperventilation had a smaller effect on corona.

EXPERIMENTAL CONDITIONS:
Supply: LTS 001
Waveform: AC, See Figure 18
Repitition Rate: 50 pps
Exposure: 22 pulses
Peak Voltage: -18 kV
Isolator: 1/4 in. glass plate
Film: Polaroid 55
Subject: Index and Middle Fingers of LTS Subject A



Notes: Subject had one finger washed in alcohol and exposures 1 and 2 were taken. Then subject hyperventilated for 1 min, and exposures 3 and 4 were taken. After a 1-min wait two more exposures were taken, but are not shown above.

Figure 12. Hyperventilation

Under the conditions of this experiment the CD photographs were probably measuring the correspondence of palm sweating with hyperventilation. As discussed earlier, there is a correspondence between subject restivity and the CD signature. However, under the conditions we used; this effect is not as pronounced as the effect of skin moisture.

Figure 12, shows that the unwashed finger was moist enough to inhibit corona formation. Because of the drying effect of the corona, it would be expected that the undryed finger would have exhibited corona upon the second exposure. However, some moisture removed by the corona discharge was apparently replaced by hyperventilation.

The second pair of exposures both attest to skin moistening. The fact that the third exposures both exhibit greater corona than the first is also of interest. Some effects of hyperventilation (increased gas content and drop in partial pressure of CO_2 in blood) should extend beyond the actual act of hyperventilation (HYPV) itself. However, during hyperventilation there is an initial vascodialation (sweating) followed by vascoconstriction (no sweating). After the drying action of the post-hyperventilation CD photography, little moisture appears to be generated in the skin.

The skin-moistening response to HYPV may have a relatively high threshold, or may occur only while the lungs are being

overactivated. Another possibility is that the physical activity associated with HYPV is responsible for some palm sweating. Any further conclusions depend on future investigations.

4.2.3 "External" Stimuli

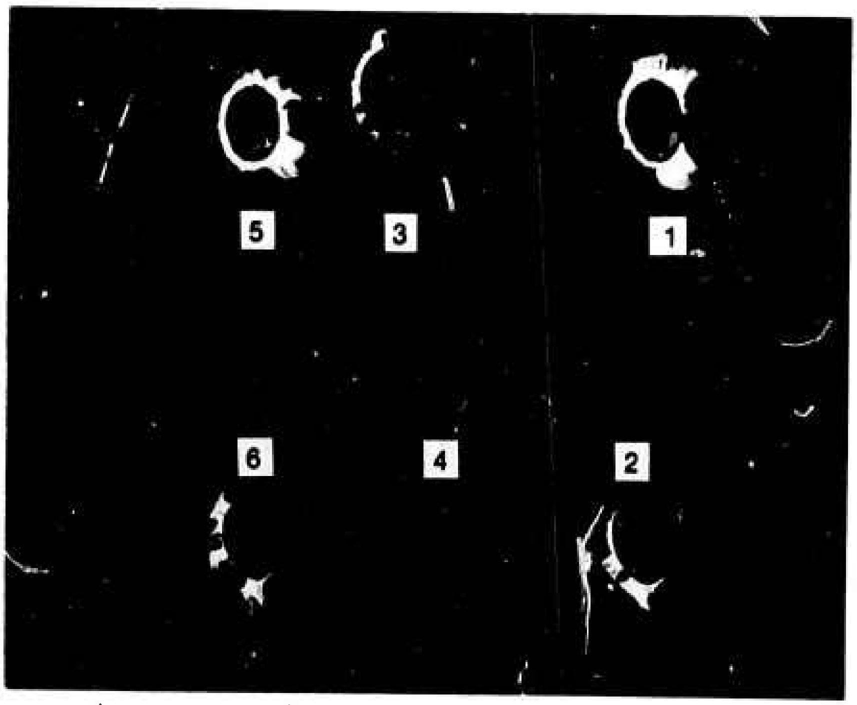
In order to evaluate the utility of CD photography as a tool for certain investigations of psychophysical behavior, a series of experiments were conducted to investigate CD photographs under conditions of mild stress. Once again, the experiments were designed so that skin moisture would be the determining factor.

- Experimental -

Three "stresses" were studied: mild pain, noise, and mental activity. The mild pain consisted of a light pinch by forceps administered to the hand of the subject; the noise was 1.5 min. of 80 dB (SPL) white noise followed by 10s 100 dB (SPL) 1000 H_z tone, and the mental arithmetic consisted of counting backwards from a 3-digit number by increments of 7 or 17. Since the purpose of these experiments was only to determine whether any correlation exists between the stresses and corona, little effort was made to control the stimuli precisely.

Six subjects were tested, and the stimuli were applied in random order. For each subject, one finger was alcohol-dried, and a control finger was not dried. The two fingers were photographed, and then the stimulus was applied. At the same time a second exposure was made. After a 1 min- "rest", a third exposure was made. Figure 13, 14, and 15,

EXPERIMENTAL CONDITIONS:
Supply: LTS 100
Waveform: DC, See Figure 20
Repitition Rate: 50 pps
Voltage Rise Time: 300 μs
Peak Voltage: -11 kV
Duty Cycle: 25%
Exposure: 75 pulses
Film: Polaroid 55
Subject: Index and Middle Fingers of LTS Subject B



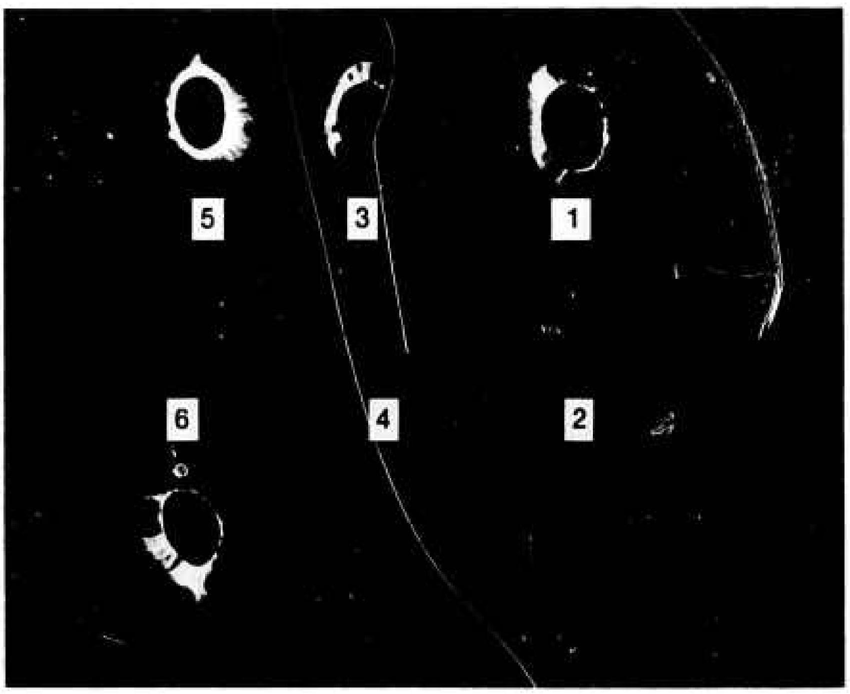
Exposures 1, 3, and 5 are the alcohol-washed finger

Exposures 2, 4, and 6 are the untreated finger

Notes: Exposures 1 and 2 were taken first. The subject was lightly pinched just before exposures 3 and 4; Exposures 5 and 6 were taken 1 min after 3 and 4.

Figure 13. Stimulus: Pinch

EXPERIMENTAL CONDITIONS:
Same as Figure 13.



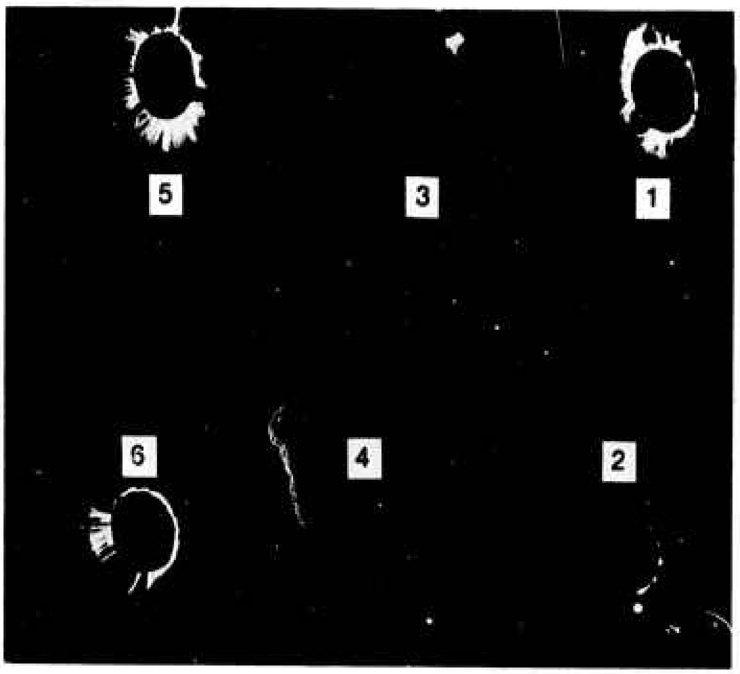
Exposures 1, 3, and 5 are the alcohol-washed finger

Exposures 2, 4, and 6 are the untreated finger

Notes: Exposures 1 and 2 were taken first. The subject performed mental arithmetic requiring concentration, before 3 and 4. Exposures 5 and 6 were taken 1 min after 3 and 4.

Figure 14. Stimulus: Mental Arithmetic

EXPERIMENTAL CONDITIONS:
Same as Figure 13.



Exposures 1, 3, and 5 are the alcohol-washed finger

Exposures 2, 4, and 6 are the untreated finger

Notes: Exposures 1 and 2 were taken first. The subject was exposed to a tone burst just prior to exposures 3 and 4. Exposures 5 and 6 were taken 1 min after 3 and 4.

Figure 15. Stimulus: Tone Burst

are the results for one of the subjects. Figure 16 is a table presenting the results for all six subjects.

In response to mental arithmetic, the change in corona was none or small. Upon pinching 5 of 6 subjects exhibited changed corona. In response to the noise 4 of the 6 subjects exhibited a reduction in corona.

- Discussion -

It was expected from published works that all of the stimuli would result in an increase in sweating. All of the subjects gave a CD-photography measurable response to at least one of the stimuli. The level of the response was loosely tied to initial sweat count.

Among subjects, different responses were greatest and least. For example, one subject's CD photograph showed no response to noise, but was sensitive to pain, another showed greater response to pain than to noise. This variation is probably due to differences among individual response to stimuli type, but may be due to variations in the conditions of and intensity of the stress. Further experiments are required to determine which.

Stimuli MA: Mental Arithmetic

P: Light Pinch

N: Noise

HV: Hyperventilation

O: No Significant Change in Streamer Range
S: Small Change in Streamer Range
M: Medium Change in Streamer Range
L: Large Change in Streamer Range
-: Film Exposure Not Acceptable

SUBJECT		MA	P	N	HV
A	Control	O 1	M	L	-
A	Alcohol Wash	O	M	L	L
B	Control	S	M	M	- 1
B	Alcohol Wash	S	M	M	M
C	Control	S	O 1	O	L
C	Alcohol Wash	O	O	O	M
E	Control	S	L	O 1	S
E	Alcohol Wash	O	L	O	S
F	Control	O 1	M	M	M
F	Alcohol Wash	O	S	O	O
G	Control	O	-	-	- 1
G	Alcohol Wash	S	L	M	L

Notes: These experiments were performed under the conditions described in Figure 13. Each subject sat for four experiments which were conducted as described in Figures 12, 13, 14, and 15. A rest period of approximately 5 min. was provided between experiments with the subject. The order of experiments was "randomized"; the 1 indicates the first experiment for each subject.

Figure 16. Results of Six Subject's Response to Stimuli

SECTION V

EXPERIMENTAL TECHNIQUES AND EQUIPMENT

5.0 GENERAL

In this section the power supplies, experimental set ups, subjects, and experimental procedures are reviewed. Further information on these subjects can be found in earlier reports under ARPA order 2812.

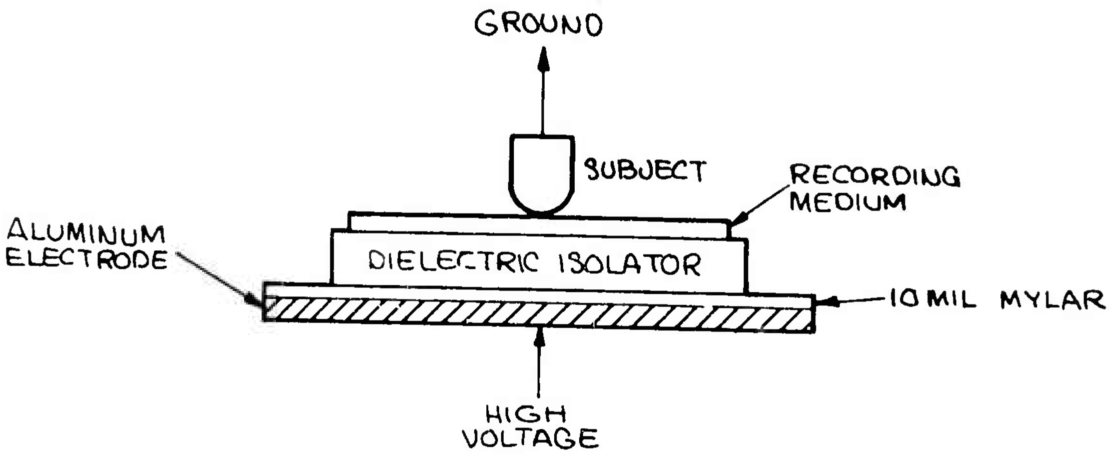
5.1 HIGH-VOLTAGE SYSTEMS

In Phase III, we have used two high-voltage systems: the LTS 001 and the LTS 100.

5.1.1 LTS 001

The LTS 001 is shown in the simplified schematic in Figure 17; the output waveform for this circuit is shown in Figure 18. The impedances R_{1p}, R_{2p}, C_{1p}, and C_{2p} are associated with a high voltage probe. The effective shunt capacity is about 25 pF, and the resistance is 500 MΩ.

The voltage developed across R_{2p} is monitored by the y channel of an oscilloscope. The voltage across R, which in effect measures current in phase with the supply voltage, is coupled either to the y channel of a scope when time dependence is of interest, or to the x channel (the sweep) when a direct display of the voltage-current characteristic is desired. The latter scope presentation is particularly useful when corona current and voltage are to be related. The other circuit parameters which are important in



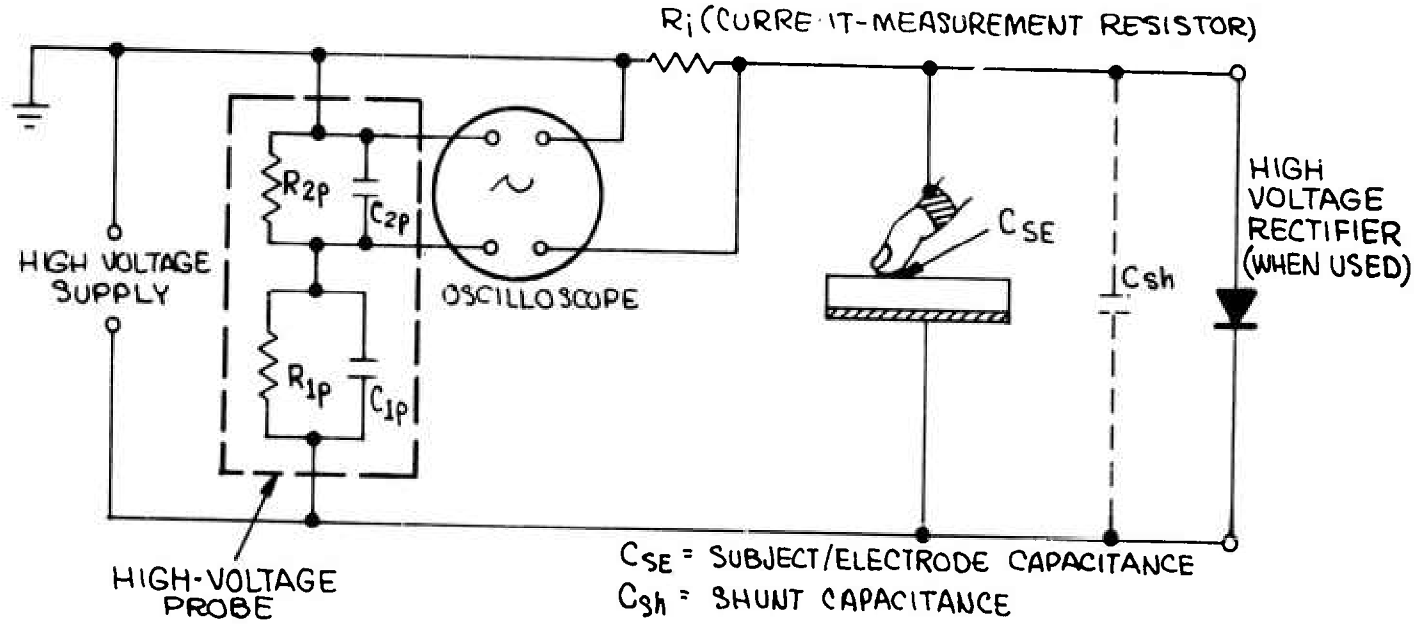
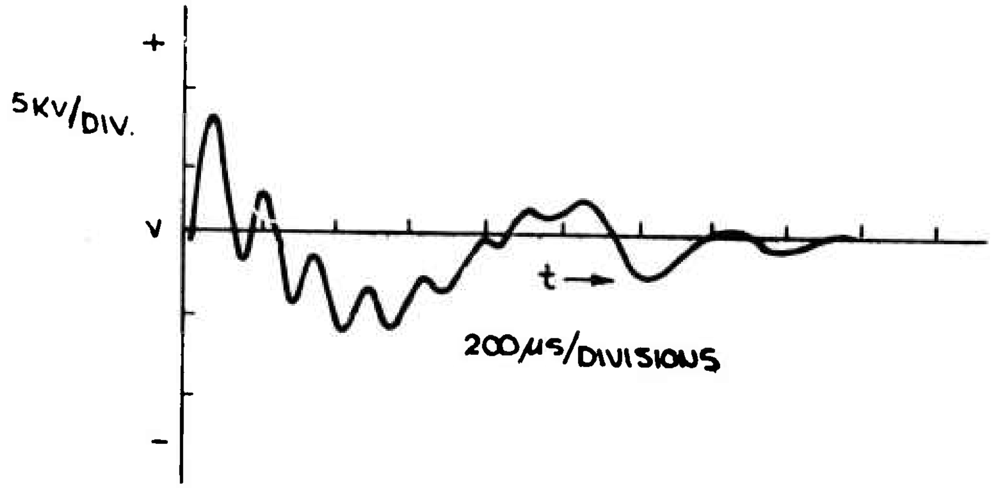
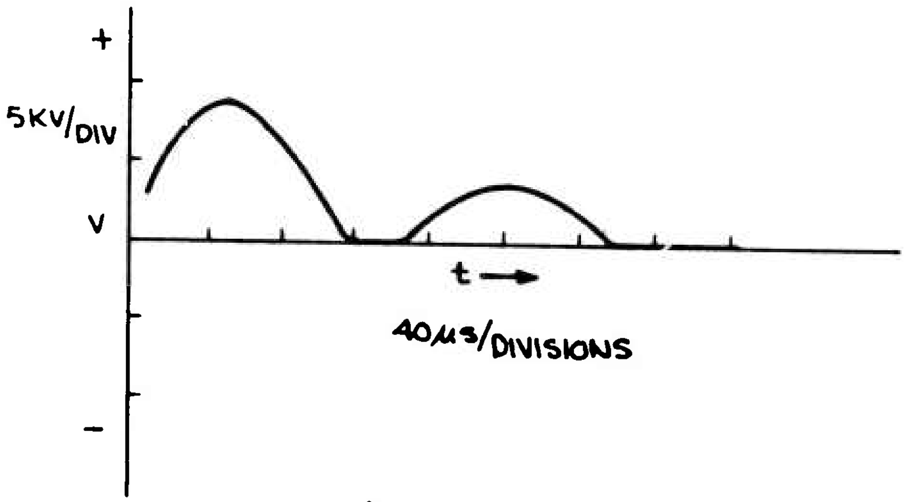


FIGURE 17. HIGH-VOLTAGE CIRCUIT for A CORONA-DISCHARGE EXPERIMENT



(a) UNRECTIFIED



(b) RECTIFIED

FIGURE 18. REPRODUCTION OF OSCILLOSCOPE TRACES OF OUTPUT VOLTAGE FROM K001 SUPPLY

determining voltage relationships, are C_{SE}, the subject to electrode capacity (with a glass isolator thickness of 1/4 inch this capacity is close to 1 pF) and C_{SH}, stray shunt capacity (associated with leads and subject) which may be as high as 20 pF.

The basic waveform is a decaying resonant oscillation in a high voltage coil, activated by capacitive discharge. Any number of oscillations can be triggered repetitively at a repetition rate of 60 per sec. The peak voltage of this supply is variable from 6 to 25 kV in either polarity. When the voltage is rectified by a shunting high-voltage rectifier the waveform has the basic characteristics shown in Figure 18b. The waveshape is the same in either polarity. The waveshape of the first voltage swing corresponds to a fundamental frequency of about 4 kHz.

5.1.2 LTS-100

A block diagram of the LTS 100 system is shown in Figure 19. The K100 function generator and the K110 high-voltage amplifier provide the voltage waveform for the electrodes. This system is a modification of the system reported in the final report for Phase III. The modifications were introduced to simplify the system by removing some of the planned capabilities to allow time for more extensive experiments.

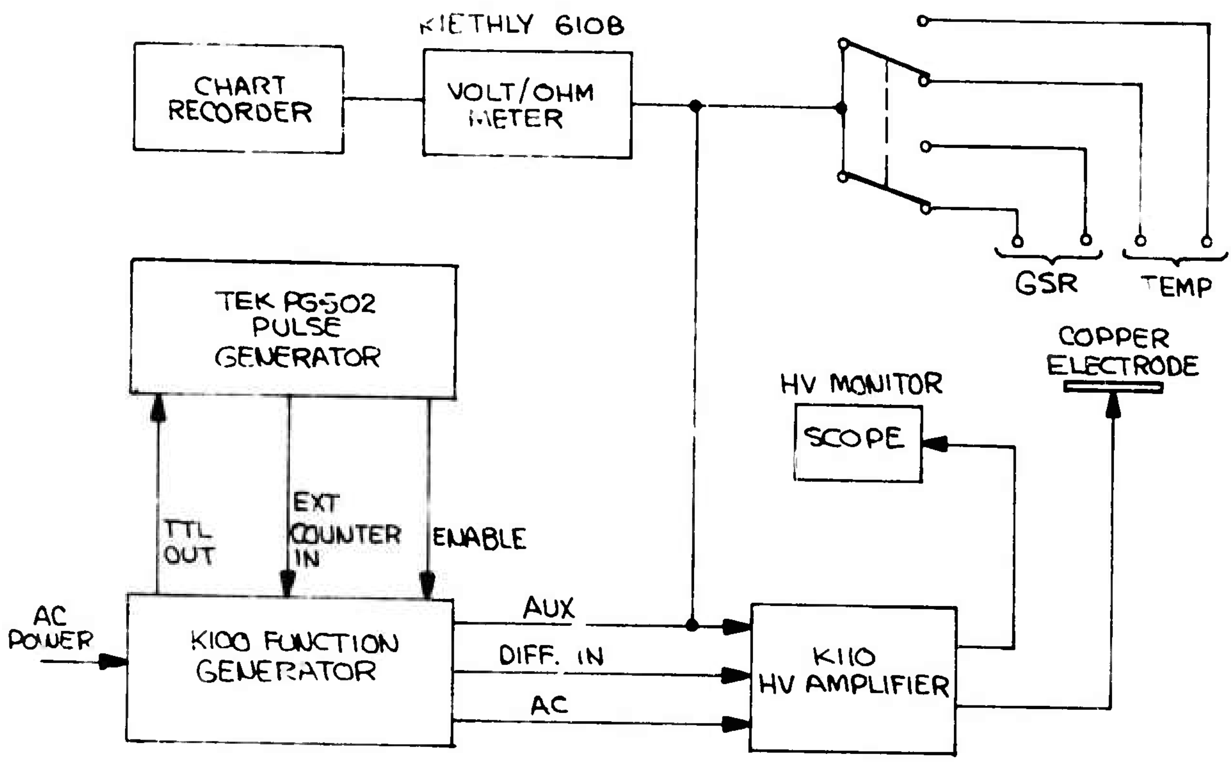


FIGURE 19 EXPERIMENTAL ARRANGEMENT USING THE LTS 100 SYSTEM

The power supply is modular, with waveform generation and control logic in a single unit. Controls are both variable and preset, and the system is capable of remote programming. Safety features include blanking of the biomedical measurements during high-voltage pulses, current limiting in the power supply, a voltage-limiting crowbar in the power output unit, and interlock controls. The high voltage cable is PVC shielded and bolted to a support table at 3 positions; during experimentations subjects are grounded between the point of high-voltage exposure (the finger) and the remainder of the body, to short any current paths past the subject hand. The dielectric isolators, mylar, and film on the electrode limit current to less than 3 mA at a pulse repetition rate of 125 pps.

The system specifications include:

Voltage:	0-to-11 kV ±5%, continuously variable
Pulse Repetition Rate:	0-to 200 Hz ±1%
Minimum Pulse Width:	200 μs
Duty Cycle Variation:	10-50%, interval
Carrier Frequency:	17 kHz
Rise Time:	up to 300 μs
Waveforms:	Triangle, sine wave, ramp, square-wave, sawtooth

Figure 20 is a scope trace of the output voltage pulse as used in the experiments discussed in Section IV.

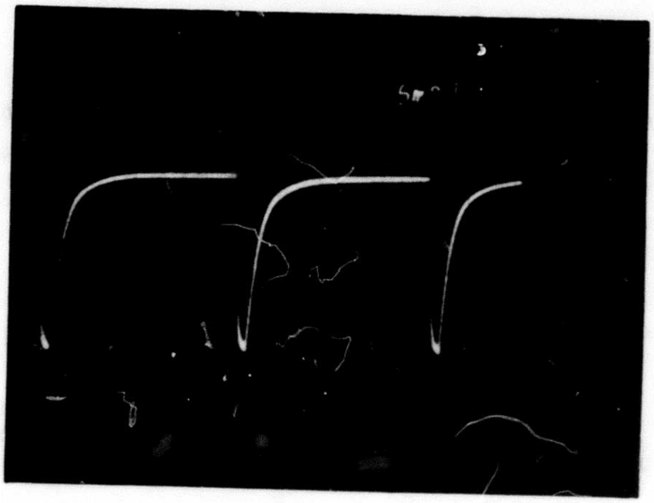


Figure 20. Scope Trace of LTS 100 High Voltage, as used in Experiments in Section IV

5.2 EXPERIMENTAL ARRANGEMENTS

5.2.1 Armrest

In using the LTS-100 system an arm and hand rest was constructed to provide pressure and position control for the photography of fingers. The rest is shown in Figure 21.

5.2.2 Subject electrode arrangements

The subject electrode configuration used with the LTS-100 system is shown in Figure 22. The finger replicas referred to in Figure 6 are shown in Figure 23.

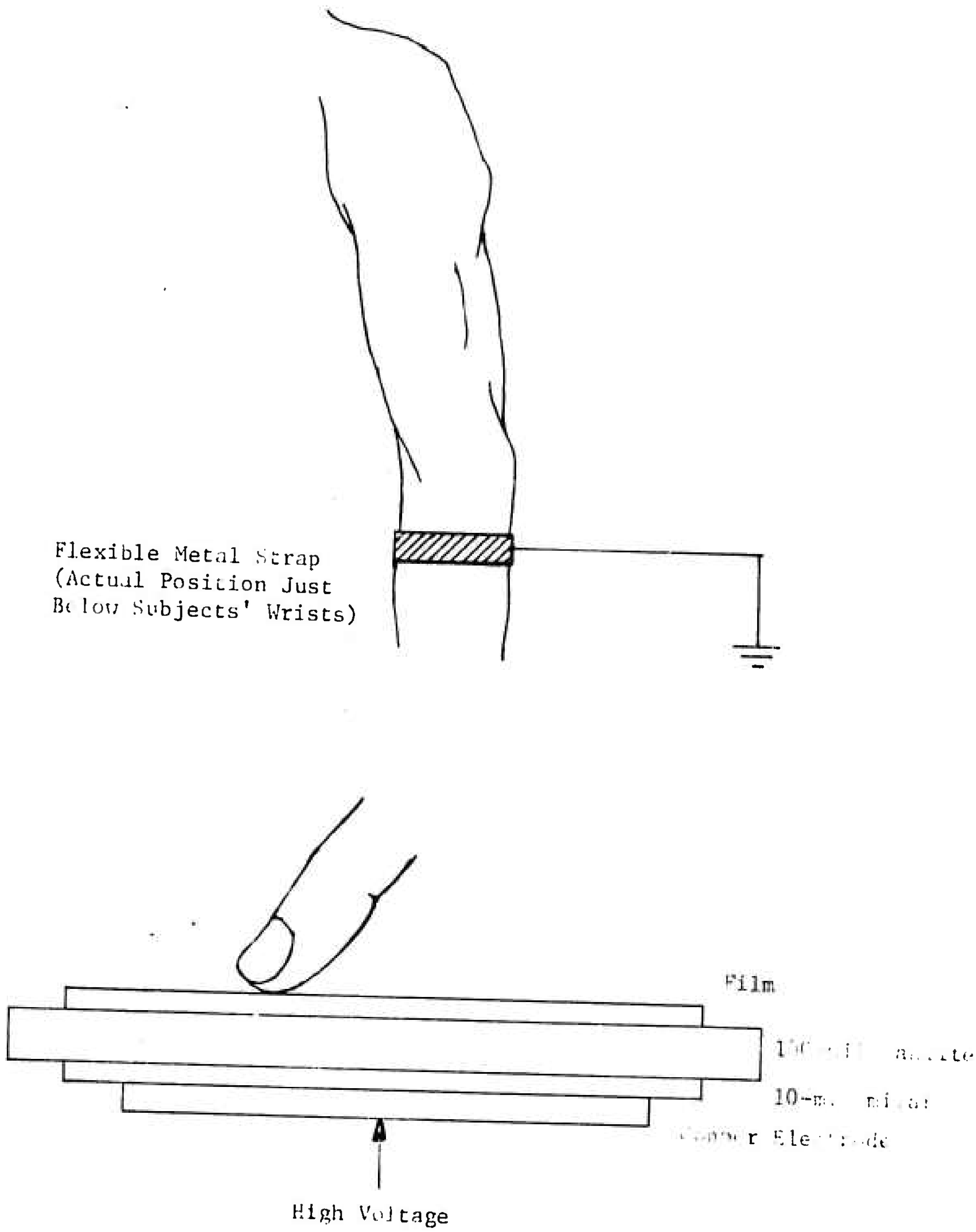
5.3 Experimental Procedures

Experimental procedures are outlined in the captions of the CD photographs showing the results discussed in Section IV.

During this period we generally used Polaroid 55 or 52 film. Film processing was carried out under controlled conditions. Ambient temperature and humidity were recorded but not controlled beyond the use of a standard air conditioning unit.

During photographs of human fingertips skin temperature and/or GSR were often recorded.

The general purpose of experiments during this phase was to determine the feasibility of CD photography as a tool in biological studies. Experimental controls were exercised to allow identification of those parameters which relate to the corona signature, but were not sufficient to allow quantitative interpretation in most cases.



([illegible] to Scale)

Fig[illegible] 2[illegible]. Electrode Configuration for [illegible]

SUPPORT PLATFORM HOLDS ARM IN RESTED POSITION. ANGLE, HEIGHT AND POSITION OF ARM ARE ADJUSTABLE. TO PERFORM AN EXPERIMENT THE ARM IS POSITIONED WHILE FILM AND ELECTRODE ARE SWUNG OUT. FILM IS THEN MOVED INTO CONTACT WITH SUBJECTS FINGER. THE ANGLE BETWEEN THE FINGER AND FILM IS ADJUSTABLE THROUGH BOTH THE SUPPORT AND THE ELECTRODE-AND-FILM HOLDER

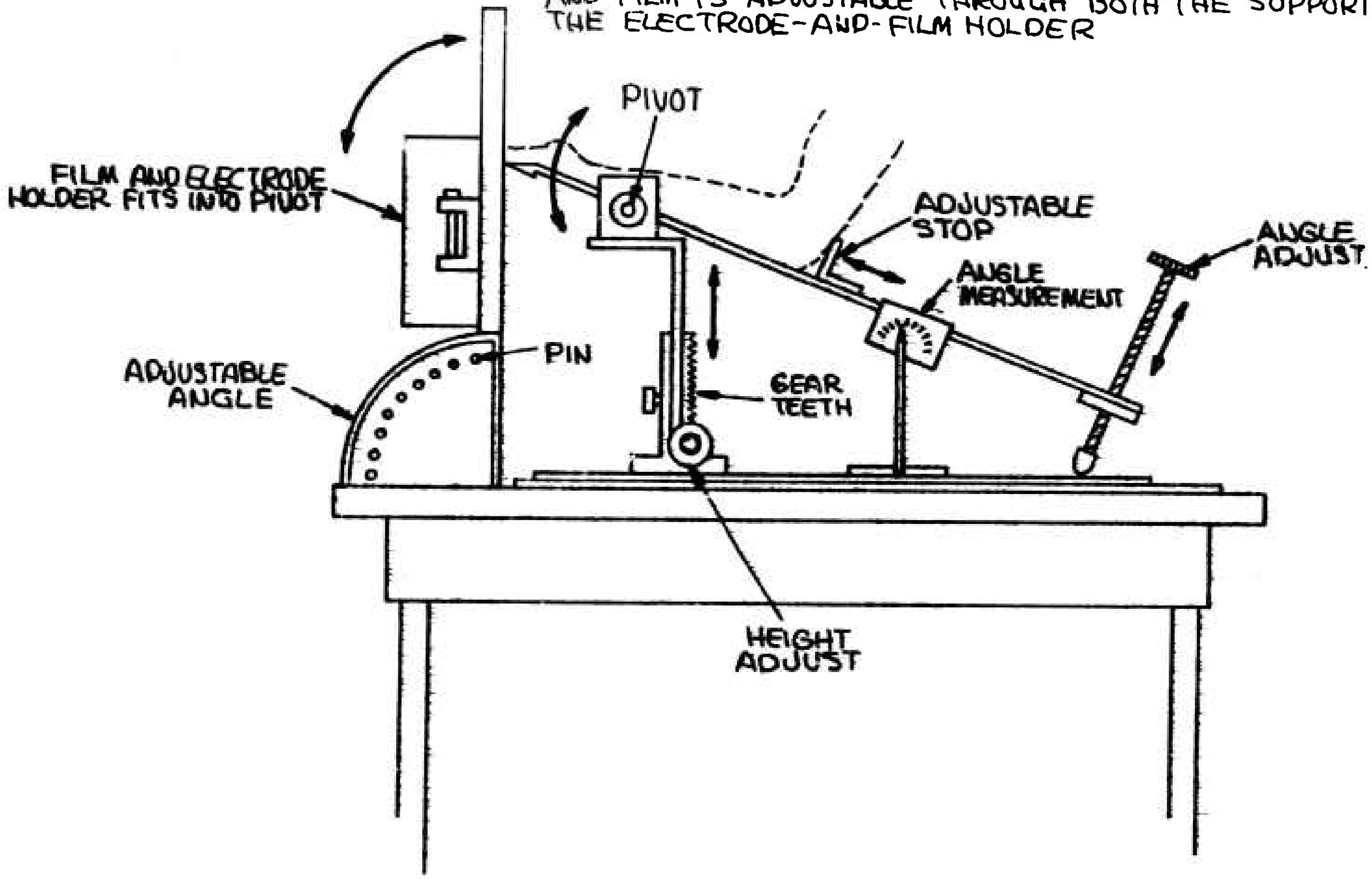


FIGURE 21. ARM AND HAND SUPPORT AND POSITIONER

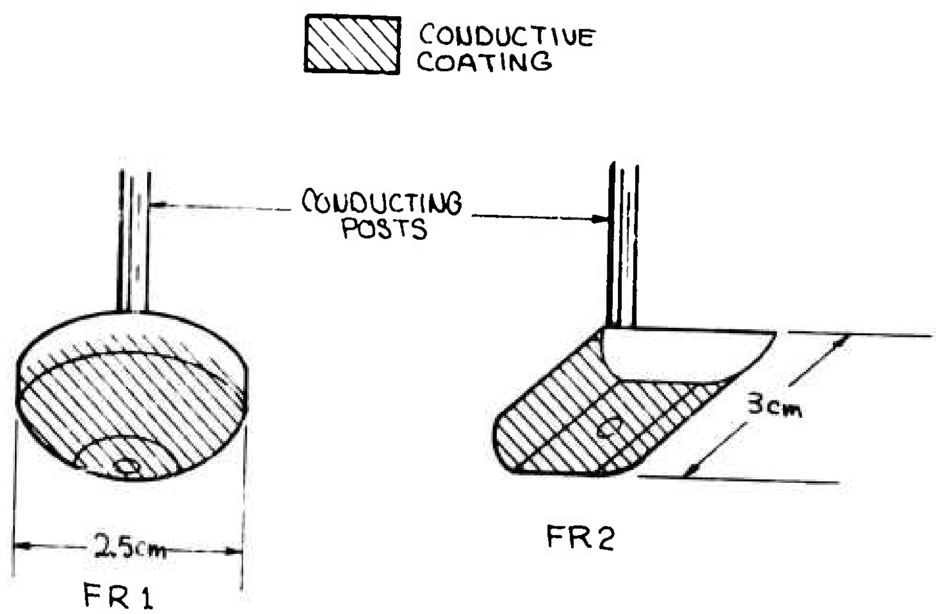


FIGURE 23. WOODEN FINGER REPLICAS

SECTION VI

APPLICATIONS

One of the requirements for Phase III was the selection of one or two possible applications of CD photography that would have been further investigated had Phase IV been instituted. Not only were we able to identify several such possible applications, but we were also able to investigate several of them to a limited extent. In one case, skin hydration studies, we were actually able to carry out the application to obtain results that are useful, independent of the CD photography technique.

We have considered applications in two broad groups: (1) Biological sciences and (2) Materials Sciences. Several possible applications in the materials sciences are described in the attached letter to Dr. Edward van Ruth, of ARPA's Materials Sciences Office.

The possible biological applications that are merit investigation are based on the experiments described in Section IV. In addition to applications based on the experiments described there, it would be worthwhile to investigate CD photography as a tool in examining cell structure.

In general, promising biological areas for investigation include studies and diagnosis of skin and diseases of the skin; the relation between skin condition and other physiological conditions; general physiological conditions and their relation to body impedance; measurement of responses to physical and psychological stimuli, and the study of tissue.

It should be pointed out that although these possible uses are suggested by the work we have done to date, they have been neither developed nor proven (with the possible exception of skin-hydration studies, for which we have strong evidence of the success of CD photography as an analytical tool)

LOGICAL TECHNICAL SERVICES CORP.
(212) 741-8340
71 West 23rd Street New York, N.Y. 10010

September 2, 1975

LTS reference Q-206

To: Dr. Edward Van Reuth
Material Sciences Office
Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, Virginia 22209

Subject: Corona-Discharge Techniques for Materials Testing and Quality Control

Last Wednesday (27 Aug. 1975) Dr. G. H. Lawrence of ARPA's Human Resources Research Division telephoned you to mention that results of our work under ARPA Order 2812 on corona-discharge ("Kirlian") photography may indicate applications and further research of interest to you. Since you stated an interest in discussing the matter with us, we are submitting here a brief outline of our findings relevant to the analysis and testing of certain materials. This should serve as a convenient basis for our discussion.

Since June 1974 LTS Corporation has been investigating the interaction of various materials with high-voltage electromagnetic fields. Under the appropriate conditions, visible corona form about the subject. Our researches have shown that the shape, intensity, threshold voltage, and streamer length of the corona are dependent in a complex manner on physical and chemical properties of the specimen in the EM field. Relevant specimen properties include capacitance, dielectric constant, conductivity, H_2O content, and topography and continuity (visible and subvisible). Relevant EM field properties include the number and rate of pulses, voltage rise time, pulse shape, and polarity. Also, in most of our work, the corona have been recorded on photographic film. Thus the corona-signature also depends on the film type used.

Because of the number of interacting variables and the limited amount of research to date, it is impossible to state with certainty what applications or uses corona discharge photography will have. Nevertheless, some of our observations

indicate that the method merits further investigation as a quality-control or testing tool:

1. Physical imperfections in a specimen can act as a preferred site for corona streamer formation.
2. Specimen impedance variations, which may be caused by deviations in internal structure, change the corona onset voltage.
3. Moisture content of certain subject types will determine the length and number of corona streamers.

These observations and some possible applications are supported by photographs taken in our laboratory. In many cases, the photographs also illustrate some of the problems in discrimination and corona interpretation that must be overcome during further research. Copies of the actual photographs are on file in our laboratory. These and a detailed description of how the corona-discharge experiment is performed will be made available upon your request.

One experiment illustrated macroscopic imperfection detection via corona-discharge photography. The subject was a piece of tin foil cut into the shape of a leaf and scribed with a pointed instrument to simulate the veins of leaves. The applied pulse was positive rectified with a fundamental frequency of 8 kHz and a voltage of approximately 13 kV.

This photograph was taken early during our research, and its primary purpose was not to demonstrate the effect of topographic changes on corona signature. Nevertheless, it illustrates that the indentations scribed on the tin foil are all clearly visable as corona formed along the scribes.

Applications taking advantage of the tendency of discontinuities to serve as corona sites might include field checking small parts such as firing pins for fractures, the inspection of uninsulated wire by rapid reeling through a corona-forming field to identify burrs or dents, or of an insulated wire to identify exposed metal.

Another experiment illustrated the effect of a change in subject impedance on a corona signature. The specimen was a wooden finger replica constructed for the investigation of the corona-signatures of human finger tips. The applied field was 8 kV at 32 kHz, and there was a 99-mil thick bakelite isolator between the film and the high-voltage electrode. The film was Polaroid Type 52. Two exposures were made on the same piece of film. In the second exposure a 1 megohm

resistance was placed between the specimen and ground. This has the effect of increasing the subject impedance without altering any other properties. In the photograph, it can be seen that the impedance reduces the streamer length. The average streamer length decreased about 70%, from 23 to 7 mil.

This type of effect may be useful in several applications. It would be worthwhile to investigate whether cell discontinuities in metallic honeycomb structures would change the impedance across the structure sufficiently to allow corona-discharge identification. It might also be possible to examine graphite-reinforced polymides and similar composite materials for regions of low graphite fiber content by operating near the corona onset voltage. A combination of impedance changes and physical discontinuties is also the basis for a potential technique for examining printed circuit boards as was shown by a further experiment.

A photograph was made showing the corona of a printed circuit (PC) board taken at 17 kV with a rectified positive pulse having a fundamental frequency of approximately 8 kHz. The board had a layer of aluminum foil attached to the reverse side with EKG paste, was separated from ground by a 1/4-in. glass plate, and separated from the film by a 7-mil mylar sheet.

A few plated-through holes on the board were "opened" by breaking the contact between the hole and the circuit lead. The corona around these "opened" holes are diminished when compared to undamaged holes.

Work to develop this process is of particular interest, since the testing of PC boards usually requires either complex and sophisticated equipment or slow and laborious manual/visual checking. It is a quality control problem common to both manufacturers and users of PC boards.

Work has also been done on the effect of surface moisture on the corona signature of a dielectric specimen. One specimen was a finger replica constructed for the investigation of corona of human finger tips. The applied field was a 17-kV rectified negative pulse with a fundamental frequency of 8 kHz. Polaroid 55 film was used with a 1/4-in. glass plate between the specimen and ground and a layer of aluminum tape between the subject and the film.

Corona were recorded for dry specimens and the same specimens with about 2 cc of water absorbed ı the surface material. There was a marked reduction in streamer extent

for the wet replicas. Further work has shown that with moderately moist subjects, the occurrence of a first corona tends to remove surface water with an efficiency at least comparable to that of an alcohol wash and air dry. Thus a series of two photographs established a "dry" baseline for for the measurement of the amount of water present in a specimen.

Besides applications in which the amount of surface moisture is the parameter of interest, this technique might be applicable in conjunction with other procedures, such as a porosity measurement taken by determining the amount of moisture adsorbed by a specimen.

It is not currently possible to utilize any of these features practically. Not only is too little known about the complex subject/field interaction, but results are not always reproducible, critical and noncritical flaws can not always be distinguished, and the interpretation of corona patterns is difficult. It is quite possible that these drawbacks could be overcome through further research, but it should also be pointed out that current theoretical and experimental evidence only suggest this as a possibility and do not guarantee it.

Experimental results to date and the potential applications do, however, justify further investigations. Corona-discharge photography might serve as a laboratory and/or field tool. It has the potential to be small, portable, fast, and simple to use.

Determination of the utility of corona-discharge photography for applications similar to those discussed here would require further investigations including:

Further study of the physics of the experiment:
- Effects of the frequency of the applied field
- Real-time formation of the corona
- Detailed and systematic investigation of the effects of variations in specific subject parameters

Further study of the kinds of apparatus used to perform the experiment:
- Effects of applied field characteristics
- Physical placement of the subject in the field
- Comparative analysis and interpretation of corona signatures
- Recording media

Further investigations of specific applications:
- Determining discrimination and sensitivity
- Effects of external parameters
- Optimum operating conditions

Development of an engineering model.

In summary, our investigations have shown that corona-discharge photography merits further investigation as a tool for the study and testing of certain classes of materials. However, such research must be considered "speculative". Rather than go into any more detail here we would like to contact you this week and arrange a date for our discussion of the general technique and its possible applications.

Yours truly,

LOGICAL TECHNICAL SERVICES CORP.

Graham L. Gross

GLG:rg

65e

SECTION VII

BIBLIOGRAPHY

The attached bibliography is a listing of publications and articles we have found relevant and/or useful during our investigation of CD photography.

1. T. E. Allibone, "Development of Spark Discharges" Nature, Vol.162 (1948), p. 263

2. T. E. Allibone, D.Sc.,Ph.D. and J. M. Meek, M. Eng. "The Development of the Spark Discharge" Royal Society of London, Proceedings, Vol.A166 (1938), p.97; A169 (1938), p. 246

3. M. R. Amin, "Fast Time Analysis of Intermittent Point-to-Plane Corona in Air; I: The Positive Point Burst Pulse Corona" J. Appl. Phys. Vol. 25 (1954), p.210

4. M. R. Amin, "Fast Time Analysis of Intermittent Point-to-Plane Corona in Air; II: The Positive Pre-Onset Streamer Corona" J. Appl. Phys., Vol.25 (1954), p.258

5. H. W. Bandel, "Point-to-Plane Corona in Dry Air" Phys. Rev., Vol.84 (1951), p.92

6. G. Barenboim, A. Domanshii, K. Turoverov (translated by R. F. Chen) "Luminescence of Biopolymers and Cells," Plenum Press, NY (1968)

7. L. Burton, W. Joines, and B. Stevens,"Kirlian Photography and Its Relevance to Parapsychological Research" Paper presented to 1974 Convention of U.S. Parapsychological Association, N.Y., August, 1974

8. James. D. Beal, "Field Effects, Known and Unknown Associated with Living Systems. 1974 IEEE Intercon technical papers, March 26-29

9. P. Chance, "Parapsychology Is an Idea Whose Time Has Come" Psychology Today, Oct. 1973, p.105

10. G. A. Dawson, "A Lifetime of Positive Streamers in a Pulsed Point-to-Plane Gap in Atmospheric Air" 2. Phys., Vol.183, p.172 (1965)

11. E. Douglas Dean, "Channel Capacity of Telepathy Channels" 1974 IEEE Intercon technical papers, March 26-29, 1974, p.1

12. H. Elden (ed.)"Biophysical Properties of Skin" Vol. I Wiley-Interscience. N.Y., N.Y., 1971

13. A. von Engel, "Ionized Gases" Oxford University Press, London, 1955

14. Von E. Flegler und H. Raether,"Untersuchung von Gasentladungs-vorgangen mit der Nebelkammer" Z.Tech. Phys., Vol.16 (1935), p.435

15. Von E. Flegler und H. Raether, "Die Ionisierungsvorgange in Gasen bei Stobspannung nach Untersuchungen mit der Nebelkammer" Z. Phys., Vol.103 (1936), p.315

16. Von E. Flegler und H. Raether, "Der elektrische Durchschlag in Gasen nach Untersuchungen mit der Nebelkammer" Z. Phys., Vol.99 (1936), p.635

17. G. G. Hudson and L. B. Loeb, "Streamer Mechanism and Main Stroke in the Filamentary Spark Breakdown in Air as Revealed by Photomultipliers and Fast Oscilloscopic Techniques" Phys. Rev., Vol.123 (1961), p.29

18. H. F. Ivey, "Electroluminescence and Related Topics" Advances in Electronics and Electron Physics, Ed. L. Marton, Academic Press, N.Y. (1963)

19. T. H. James,"The Theory of the Photographic Process" MacMillan Co., N.Y., 3rd Ed. (1966)

20. A. F. Kip, "Positive Point-to-Plane Discharge in Air at Atmospheric Pressure" Phys. Rev., Vol. 54 (1958), p.139

21. A. F. Kip, "Onset Studies of Positive Point-to-Plane Corona in Air at Atmospheric Pressure" Phys. Rev., Vol. 55 (1939), p.549

22. R. Kluckow, "Zur Messung des Zeitlechen Anstiegs des Stuomes beim statischen Durchschlag" Z. Phys., Vol.148 (1957), p.564

23. S. Konev, (Translated by S. Udenfriend) "Fluorescence and Phosphorescence of Proteins and Nucleic Acids" Plenum Press, N.Y. (1967)

24. L. B. Loeb and W. Leigh, "Positive Needle-Point Corona Studies at Atmospheric Pressure" Phys. Rev., Vol.51 (1937), p.149

25. L. B. Loeb, J. H. Parker, E. E. Dodd and W. N. English "The Choice of Suitable Gap Forms of the Study of Corona Breakdown and the Field Along the Axis of a Hemispherically Capped Cylindrical Point-to-Plane-Gap" Review of Sci. Inst., Vol.21 (1950), p.42

26. L. B. Loeb and A. F. Kip, "Electrical Discharges in Air at Atmospheric Pressure; The Nature of the Positive and Negative Point-to-Plane Coronas and the Mechanism of Spark Propagation" J. Appl. Phys., Vol.10 (1939), p.142

27. J. M. Meek and J. W. Craggs, "Electrical Breakdown of Gases" Clarendon Press, Oxford (1953)

28. V. H. Mielke, "Der zeitliche Stronmanstieg bei der statischen Durchbruchsspannung in Luft, Wasserstoff und Sauerstoff" Z. Angew. Phys., Vol.11 (1959), p.409

29. John Mihalasky, "The Role of the Unconscious in Problem Solving and Idea Generation" 1974 IEEE technical papers March 26-29

30. C. G. Miller and L. B. Loeb, "Positive Coaxial Cylindrical Corona Discharges in Pure N_2, O_2 and Mixtures Thereof" J. Appl. Phys., Vol.22 (1951), p.494

31. C. G. Miller and L. B. Loeb, "Negative Coaxial Cylindrical Corona Discharges in Pure N_2, O_2 and Mixtures Thereof" J. Appl. Phys., Vol.22 (1951), p.614

32. C. G. Miller and L. B. Loeb, "Starting Potentials of Positive and Negative Coronas with Coaxial Geometry in Pure N_2, O_2 and Various Mixtures at Pressures From Atmospheric to 27mm" J. Appl. Phys., Vol.22 (1951), p.740

33. E. Nasser and L. B. Loeb, "Impulse Streamer Branching from Lichteburg Figure Studies" J. Appl. Phys., Vol.34 (1961), p.3340

34. C. B. Neblette, "Photography, Its Material and Processes" Van Nostrand Co., Inc., Princeton, N.J., 6th ed., (1962)

35. R. W. B. Pearse and A. G. Gayden, "The Identification of Molecular Spectra" John Wiley & Sons, Inc., N.Y., (1963)

36. J. Pfave und H. Raether, "Oszillographische Beobachtungen zum Kanalaufbau in Dampfen I" Z. Phys., Vol.153 (1959), p.523

37. L. E. Reukema, "The Relation Between Frequency and Spark-Over" Trans. Am. Inst. Elec. Eng., Vol.47 (1927), p.38

38. H. Ritz, Arch. Electrotech 26, 219 (1932)

39. Time, 4 March 1974, p.65, "Bo m Times on the Psychic Frontier"

40. J. K. Vogel, "Über den Nachweiss einzelner Elekronenlawiner und ihner Sekundarprozesse in Gasen" Zeitschrift fur Physik, Vol. 148, (1957), p.355

41. Welcher, "Standard Methods of Chemical Analysis" D. Van Nostrand Co., Inc.

42. Aaronson, Steve, "Pictures of an Unknown Aura" The Sciences, Vol. 14 No.1, Jan./Feb. 1974, p.15

43. Colligan, Douglas, "Photographing the Human Aura" Science Digest, May 1974, p.11

44. Dakin, H. S., High-Voltage Supply for Corona-Discharge Photography, 1973, Private Publication

45. International Medicine News Service, "Aura Seen with Kirlian Photography is Called Diagnostic of Disease"

46. T. Moss and K. Johnson, "Radiation Field Photography" Pyschic Magazine, July 1972, p.50

47. Newsweek, 4 March 1974, p.52 "Parapsychology: The Science of the Uncanny"

48. Schwartz, Eric, "High Frequency Filter Model for Kirlian Photography."

49. Suzuki, Toshio, "Transition from Primary Streamer to Arc in Negative Point-to-Plane Corona" J. Appl. Phys., Vol. 44 No. 10, Oct. 73, p.4534

50. W. Joines, Private Communication

51. S. Brown and W. P. Allis, "Basic Data of Electrical Discharges" Technical Report 283, Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Mass.

52. L. Loeb, "Electrical Coronas, Their Basic Physical Mechanisms" University of California Press, Berkeley, Calif., 1965

53. Handbook of Chemistry and Physics, R. Weast (Ed.) The Chemical Rubber Co., Cleveland, Ohio, 1952

54. D. G. Boyers and William A. Tiller, "Corona Discharge Photography" J. Appl. Phys., Vol. 44 (1973), p.3102

55. T. Moss and K. Johnson in "The Kirlian Aura" S. Krippner and D. Rubin (Eds.) Anchor Press, Garden City, N.Y. (1974) p.51

56. Mayoux, C. and Geldman, G, "Partial Discharges in Solid Dielectrics and Corona Discharge Phenemena" J. Appl. Phys., Vol 44 (1973), p. 3940

57. J. H. Merrill and A. Von Hipple, J. Appl. Phys., Vol. 10 (1939), p. 873

58. H. D. Hagstrum "Electron Emission from Solids by Particles Carrying Potential Energy" Tenth International Conf. of Phenomena in Ionized Gasses, Vol 2 (1971)

59. V. Veimer and K. Kudu, "The Development of HF Point-to-Plane Corona" Tenth International Conf. of Phenomena in Ionized Gasses, Vol 1 (1971) p. 165

60. E. Kuffel and M. Abdullah "High Voltage Engineering" Pergamon Press, Elmsford, N.Y. (1970)

61. L. A. Geddes "Electrodes and the Measurement of Bioelectric Events" Wiley-Interscience, New York (1972)

62. P. Strong "Biophysical Measurements" Tektronix, Inc. Beaverton, Oregon (1970)

63. G. H. Brown, J.W. Doane, V. D. Neff "A Review of the Structure and Properties of Liquid Crystals" Chemical Rubber Company Press, Cleveland, Ohio (1971)

64. A. N. Zaidsl, V. K. Proffof'ev, S. M. Raiskii, V. A. Slavnyi, E. Ya. Shreider "Tables of Spectral Lines" IFI/ Plenum, N.Y. (1970)

65. T. Moss, J. Hubacher, and F. Saba "Visual Evidence of Bio-energetic Interactions Between People?" American Psychiatric Association Conference (May 1971)

66. T. Moss, K. Johnson, F. Saba "Photographic Evidence of Acu-puncture Point Stimulation" (November 1973)

67. T. Moss, K. Johnson, and A. F. Chang "Effects of Alcoholic Consumption in People As Observed Through Electrical Field Photography"

68. T. Moss, K. Johnson, M. Barshay, J. Hubacher, and J. I. Gray "Photographic Evidence of Healint Energy of Plants and People" Dimensions of Healing Symposium (1972)

69. J. Hubacher and Thelina Moss "The 'Phantom Leaf Effect' as Revealed Through Kirlian Photography"

70. Venables, P. H. and I. Martin. "Skin Resistance and Skin Potential". In Venables, P. H. and I. Martin. Eds. A Manual of Psychophysiological Techniques John Wiley & Sons, New York, 1967

71. Edelberg, R. "Electrical Properties of The Skin". In Brown, C. C. Ed. Methods in Psychophysiology. William & Wilkens Co. Baltimore, 1967

72. Sutarman M. L. and M. L. Thomson "A New Technique for Enumerating Active Sweat Glands in Man." J. Physiol. (London) 117, 52 (1952)

73. Venables, P.H. The Relationship between P.G.R. and Temperature and Humidity Quart. J. Expl. Psychol. 7, 12 (1955)

74. Yates, J. R. "Mechanism of Water Uptake by Skin". In Elden, H. R. Ed. Vol. 1. Biophysical Properties of the Skin. Wiley-Interscience. New York 1971

75. Joseph, N. R. "Dependence of Electrolyte Balance on Growth and Aging of Cells and Tissues" In Elden, H. R. Vol. 1 Biophysical Properties of the Skin. Wiley: Interscience: New York, 1971

76. Prosser, C. L. and F. A. Brown Comparative Animal Physiology 2nd Ed. W. B. Saunders, Phila. 1961 Chapters 2 and 3. Role of Inorganic Ions and Osmosis in Permability of Skin.

77. Geise, A.C. Cell Physiology and Ed. W. B. Saunders: Phila. 1962

78 Brown, C. C. "The Techniques of Plethysmography" In. Brown, C. C. Ed. Methods in Psychophysiology. William and Wilkens, Co. Baltimore, 1967

79. Edelberg, P. "Response of Cutaneous Water Barrier to Ideational Stimulation" J. Comp. Physiol. Psychol. 61, 28 (1966)

80. Randall, W. C., & Peiss, C. N. "The Relationship between Skin Hydration & The Suppression of Sweating" J. of Invest. Dermatology 28, 435 (1957)

81. Adams, T. Vaughan, J. A. "Human Sweat Gland Activity and Palmer Electrical Skin Resistance". J. of Appl. Physiology 20, 980 (19650

82. S. Rothman "Phiosology & Biochemistry of the Skin" University of Chicago Press, Chicago (1954)

83. Y. Kuno "Human Perspiration" Charles C. Thomas, Springfield, Ill. 1956

84. A. Montagna & P. F. Parekhal "The Structure and Function of of Skin" Academic Press, New York, (1974)

85. Buettner J.J.K., "Diffusion of Water Vapor Through Small Areas of Human Skin in Norm Environment" J. Applied Physiology 14, 269, 1959

86. Buettner K. J. K., "Diffusion of Liquid Water Through Human Skin J. Appl. Physiology 14, 261, 1959

87. Case, E. & Fadner, W. "A Physical Study of Kirlian Photographing" APS meeting